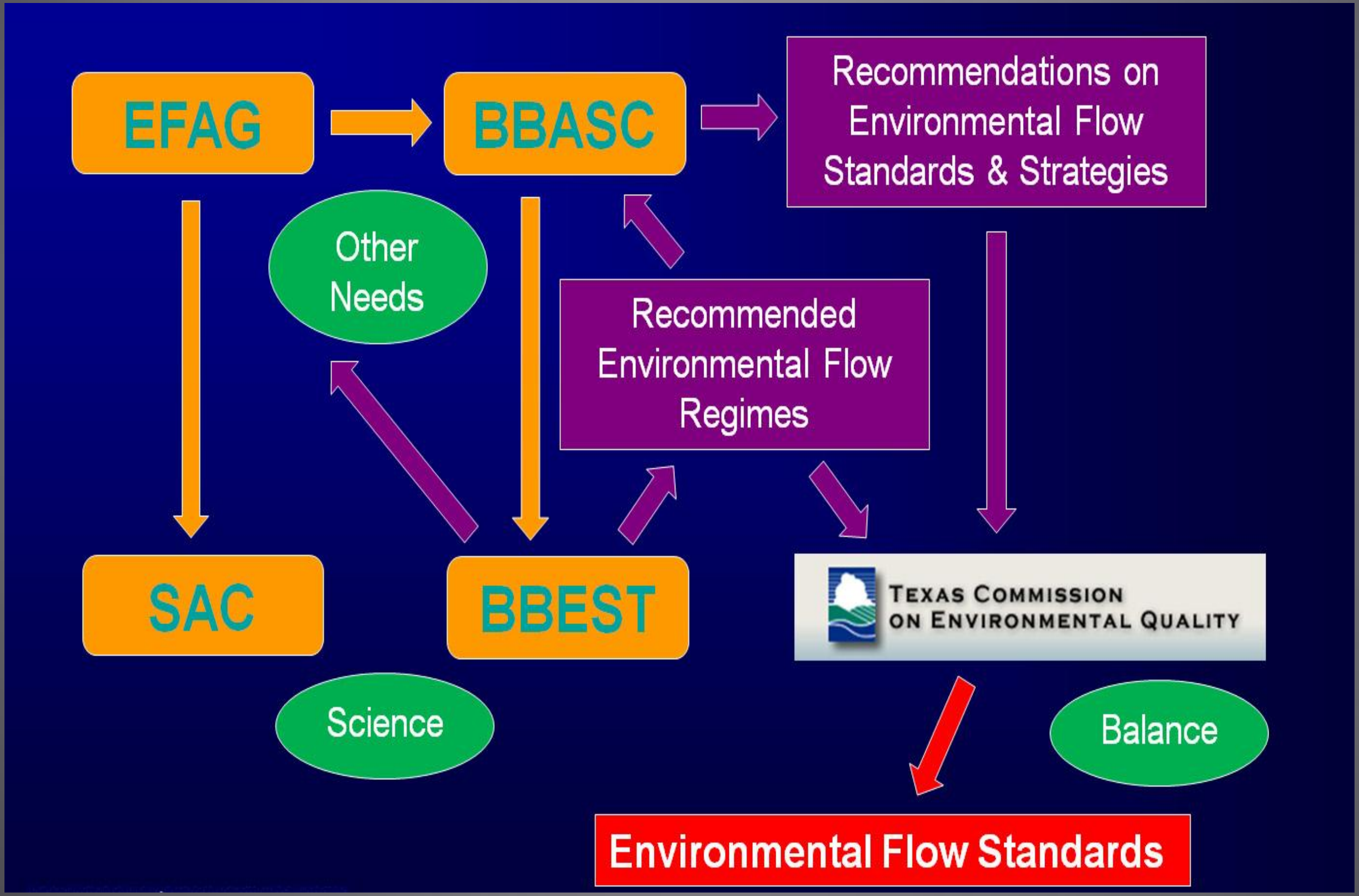
Lower Rio Grande and Lower Laguna Madre BBEST Report

Summary
July 2012

BBEST members: Hudson DeYoe (chair), Jude Benavides, Robert Edwards, Warren Pulich, Carlos Marin, David Buzan

The Process



Flow chart by Sam Vaugh, Nueces BBEST

Basin & Bay Expert Science Team (BBEST)

1) **Comprised of technical experts with knowledge of the river basin and bay system and of methods for developing environmental flow regimes.**
2) **LRG-LLM BBEST performs freshwater inflow analyses based on best available science/data and recommends environmental flow regimes through a consensus process.**
3) **Provide environmental flows recommendations by June, 2012.**
4) **Provide technical support to the LRG BBASC in its development of recommendations on environmental flow standards & strategies, and their work plan.**

BBEST Profile

Hudson DeYoe	Chair, Lower Laguna Madre Co-lead	University of Texas-Pan American, Edinburg, TX
Dave Buzan	Vice-chair, Resaca and Arroyo Colorado Lead	Atkins Global, Inc., Austin, TX
Jude Benavides	Hydrology Co-lead	University of Texas at Brownsville, Brownsville, TX
Carlos Marin	Hydrology Co-lead	Ambiotec, Inc., Brownsville, TX
Robert Edwards	Rio Grande Lead	University of Texas-Pan American, Edinburg, TX
Warren Pulich	Lower Laguna Madre Co-lead	Texas State University, San Marcos, TX

BBEST Charge and Goal

Each basin and bay expert science team shall develop environmental flow analyses and a recommended environmental flow regime for the river basin and bay system for which the team is established through a collaborative process designed to achieve a consensus.

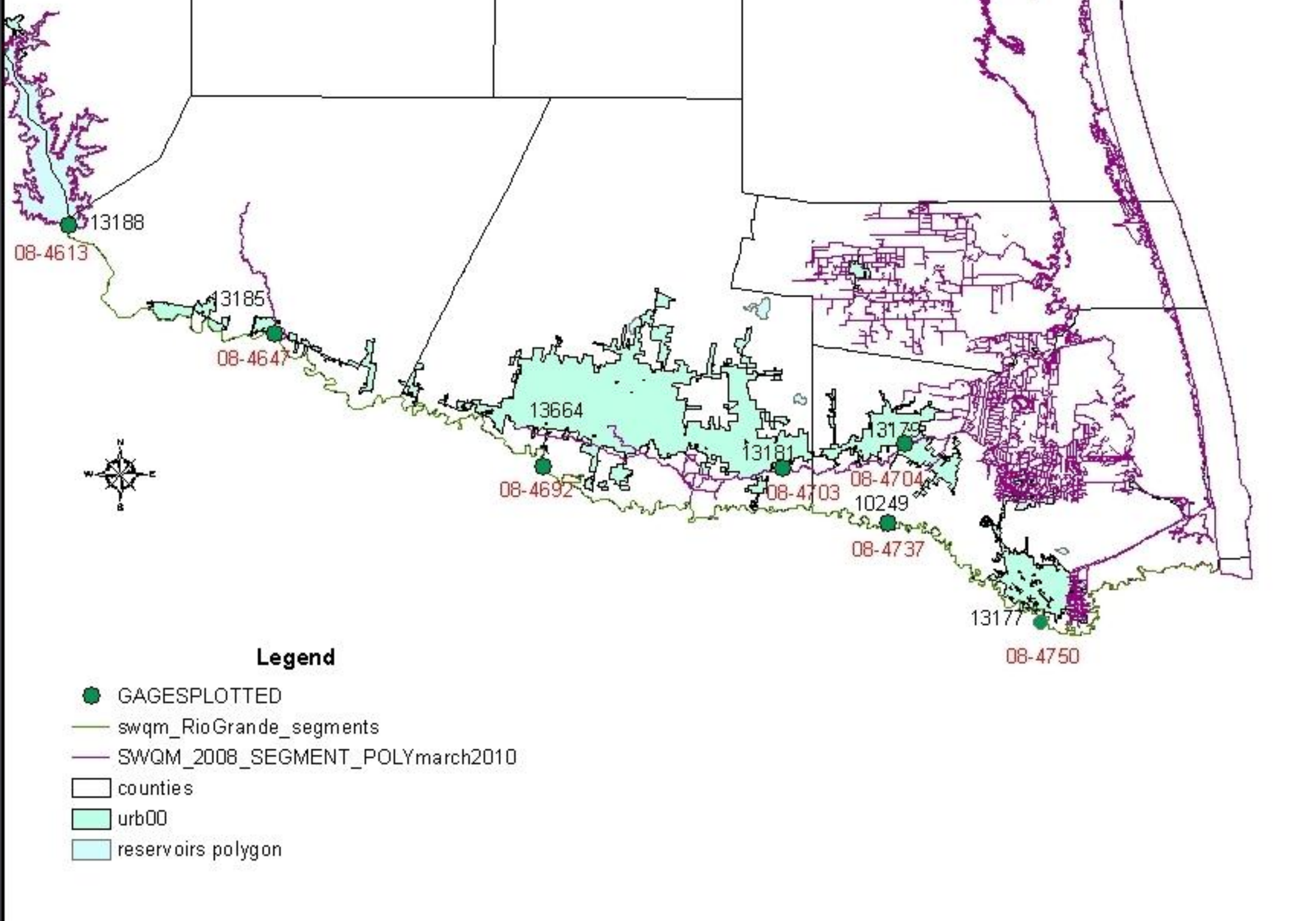
In developing the analyses and recommendations, the science team must consider all reasonably available science, without regard to the need for the water for other uses, and the science team's recommendations must be based solely on the best science available.

Goal: Develop an Environmental Flows Recommendations Report for consideration by BBASC and TCEQ

BBEST Project Area

- Six geographically regions:
  - Lower Laguna Madre Estuary (LLM)
  - Tidal portion of the Rio Grande
  - Above-tidal portion of the Rio Grande up to Anzalduas Dam
  - Arroyo Colorado
  - Resacas
  - Coastal basins between the LLM and the Rio Grande tidal.

Lower Rio Grande and Arroyo Colorado



Sound Ecological Environment

- The BBEST charge is to develop flow regimes “adequate to support a ‘sound ecological environment’ and to maintain the productivity, extent and persistence of key aquatic habitats in and along the affected water bodies.”
- A sound ecological environment (modified from SAC definition):
  - Maintains native species,
  - Is sustainable, and
  - Is a current condition. Current condition represents the condition from some year to present identified by the BBEST. The period of current condition may be defined differently for each body of water.

Bahia Grande/San Martin Lake

- The Bahia Grande is not a sound ecological environment due to anthropogenic alterations, but may become more so with the construction of a new wider channel.
- Because there is little data available, we offer no opinion about whether San Martin Lake is a sound ecological environment.

Resacas

•232 miles, covering 130 square miles – old Rio Grande channel
•113 miles of oxbows – cutoff bends in the Rio Grande and Arroyo Colorado

Ecology
Rare fish and salamanders
Riparian vegetation – roosting, nesting, and feeding for wildlife and migratory songbirds

Resacas

- Resacas should not be considered sound ecological environments when compared to their historical condition before the early 1800s. Their hydrology has been substantially altered since dams and flood control structures have eliminated flooding from the Rio Grande which historically was one of their primary sources of water.
- BBEST recommendation: Maintain depth, water, and riparian vegetation of existing resacas and oxbows

Arroyo Colorado

Freshwater

- 63 miles
- Wastewater and ag return flows dominate in dry weather
- Limited quality aquatic habitat, inadequate habitat and water quality

Saltwater

- 26 miles: Harlingen to Lower Laguna Madre
- Estuary for fish, shrimps, and crabs
- Poor water quality in upper end (low dissolved oxygen)

Habitat change and wastewater dominated flow degrade the above tidal and in upper reaches of the tidal Arroyo.

Arroyo Colorado

- BBEST does not consider the Arroyo Colorado a sound environment in regard to flow because the current flow does not support a healthy, diverse, sustainable community of native fish and shellfish along its entire length and because the sources of flow degrade water quality in the upper 15 river miles of the Arroyo.

BBEST recommendation:

Continue reducing waste loading to the Arroyo and explore ways to improve habitat

Lower Laguna Madre

- Several lines of evidence support the BBEST’s determination that the Lower Laguna Madre Estuary environment has been “sound” from the early 1960s, but that it appears to be undergoing detrimental changes over the last 15-20 years.

The Evidence

- The LLM is famous for its lush seagrass beds. LLM seagrass has decreased from its peak of 59,153 ha in the 1960s, to 46,558 ha in mid-1970s, and then to 46,174 ha in 1998. More losses have followed.
- Long-term maintenance of normal estuarine fishery populations would appear to be possible only within the context of a generally sound estuarine environment.
- There has undeniably been a fundamental change in hydrology of LLM since the late 1950s due to the dredging of the GIWW (1952) and the opening of Mansfield Pass (1958).
- Seagrass changes and phytoplankton blooms have been accompanied by increased freshwater drainage from the Arroyo Colorado and other sources.

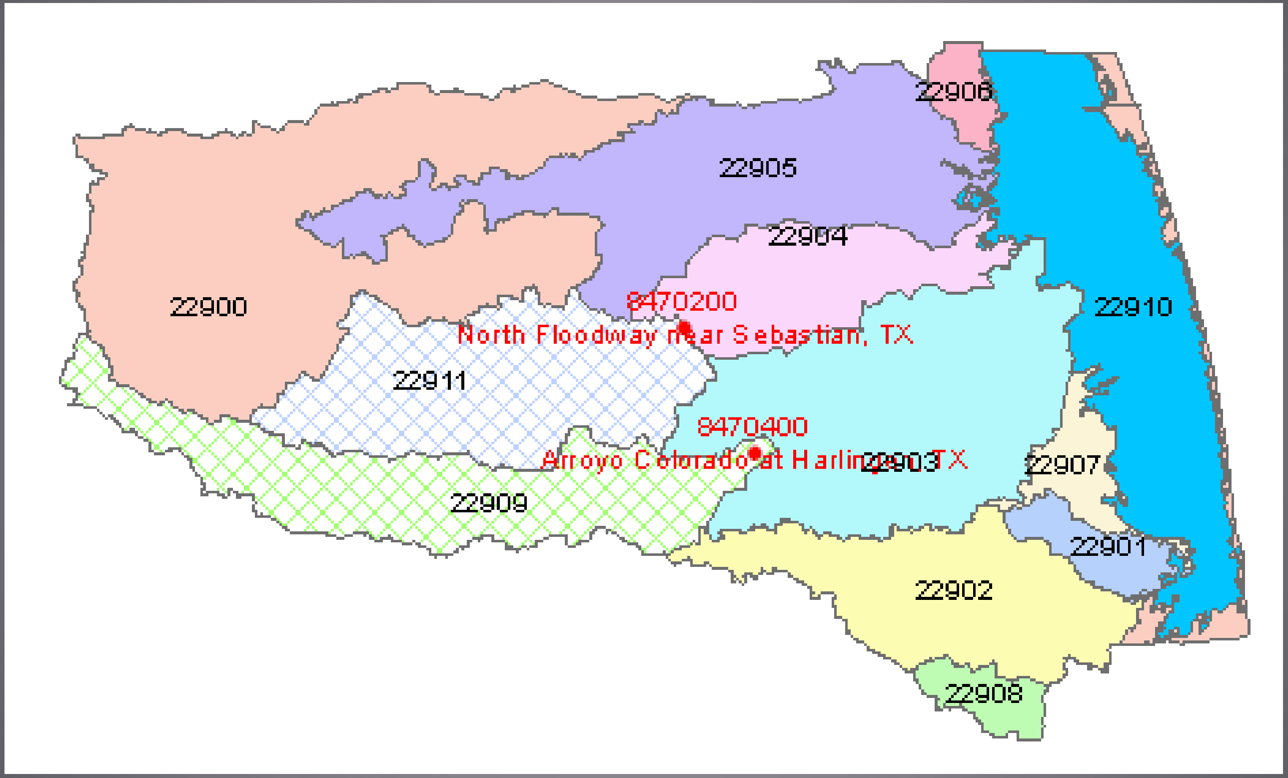
BBEST LLM Analyses & FWI Recommendations

1) Overview of Lower Laguna Madre
2) Sound Ecological Environment ?
3) Inflow Regime Analyses of Focal Species/Habitats
4) Hydrology and Water Quality Analyses
5) Environmental Flow Regime Recommendations
6) Adaptive Management Issues

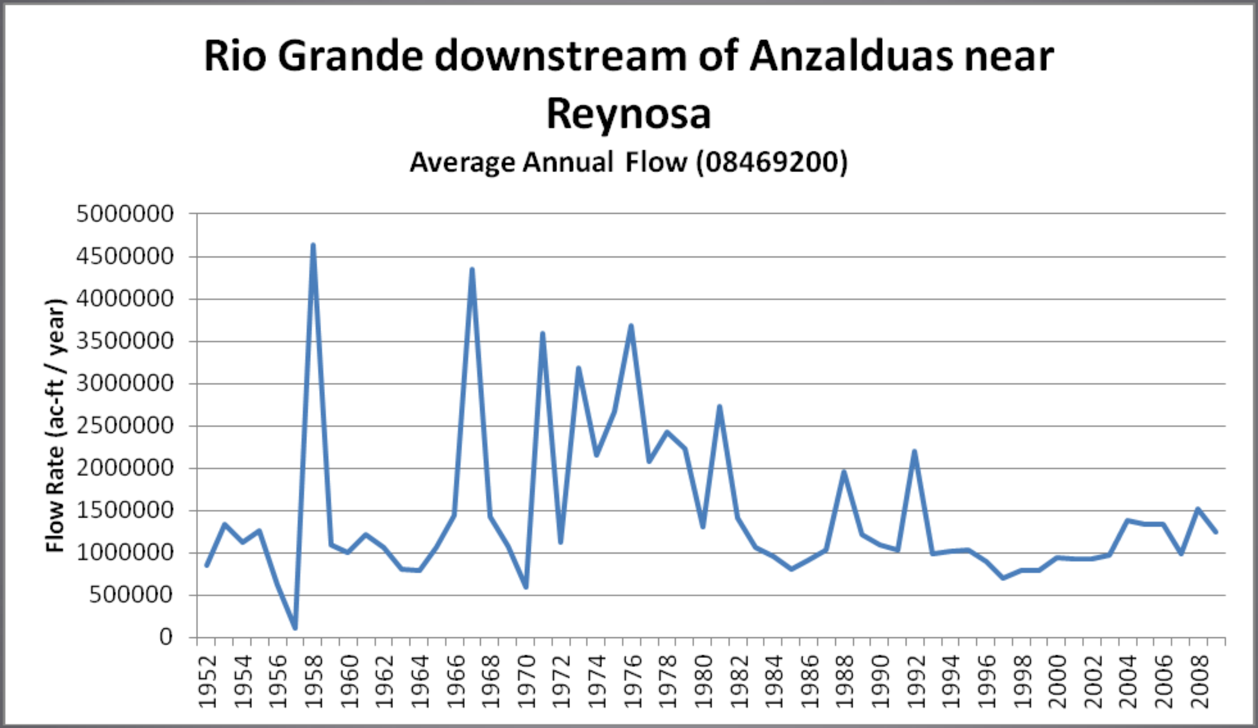
Hydrologic Considerations

Major Watersheds in Study Area

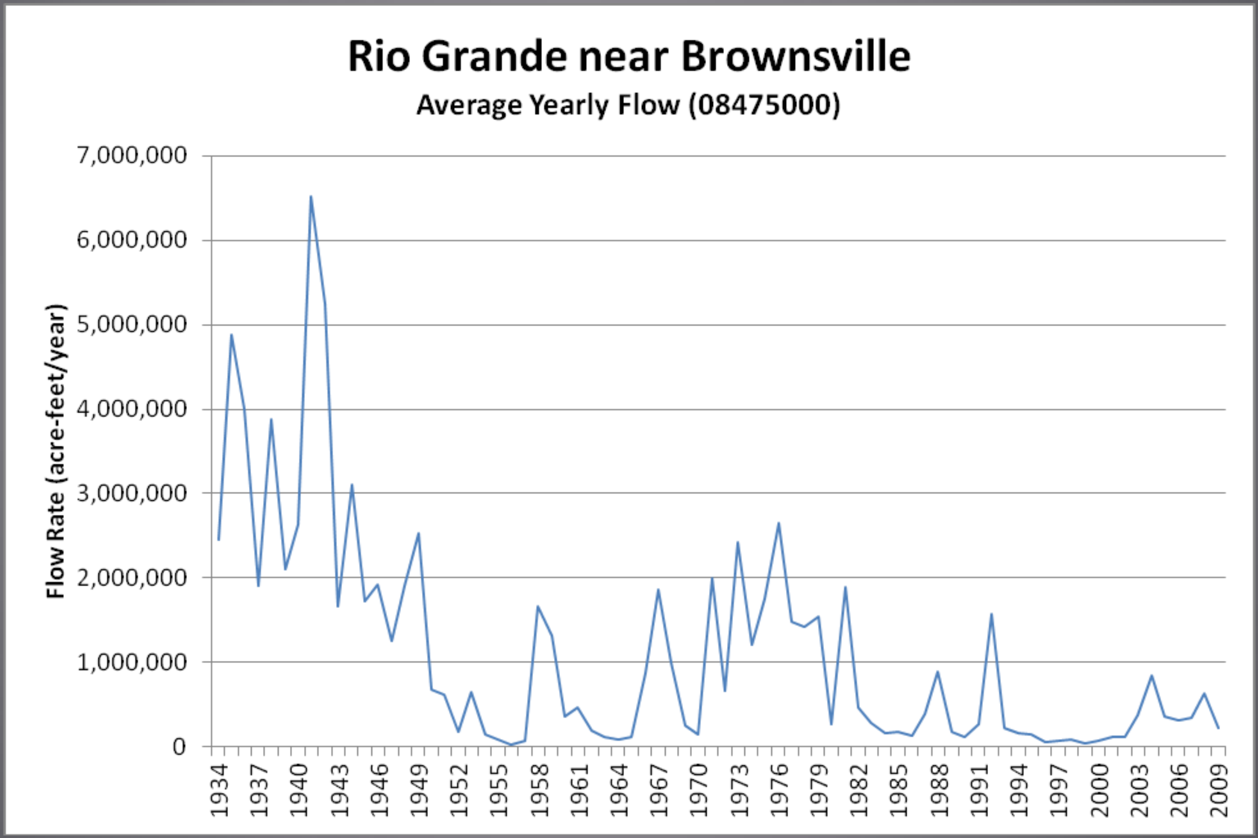
TWDB Coastal Hydrology Technical Report – Subwatersheds in Study Area



Rio Grande – Anzalduas
Average Annual Flows for POR (1952-2009)

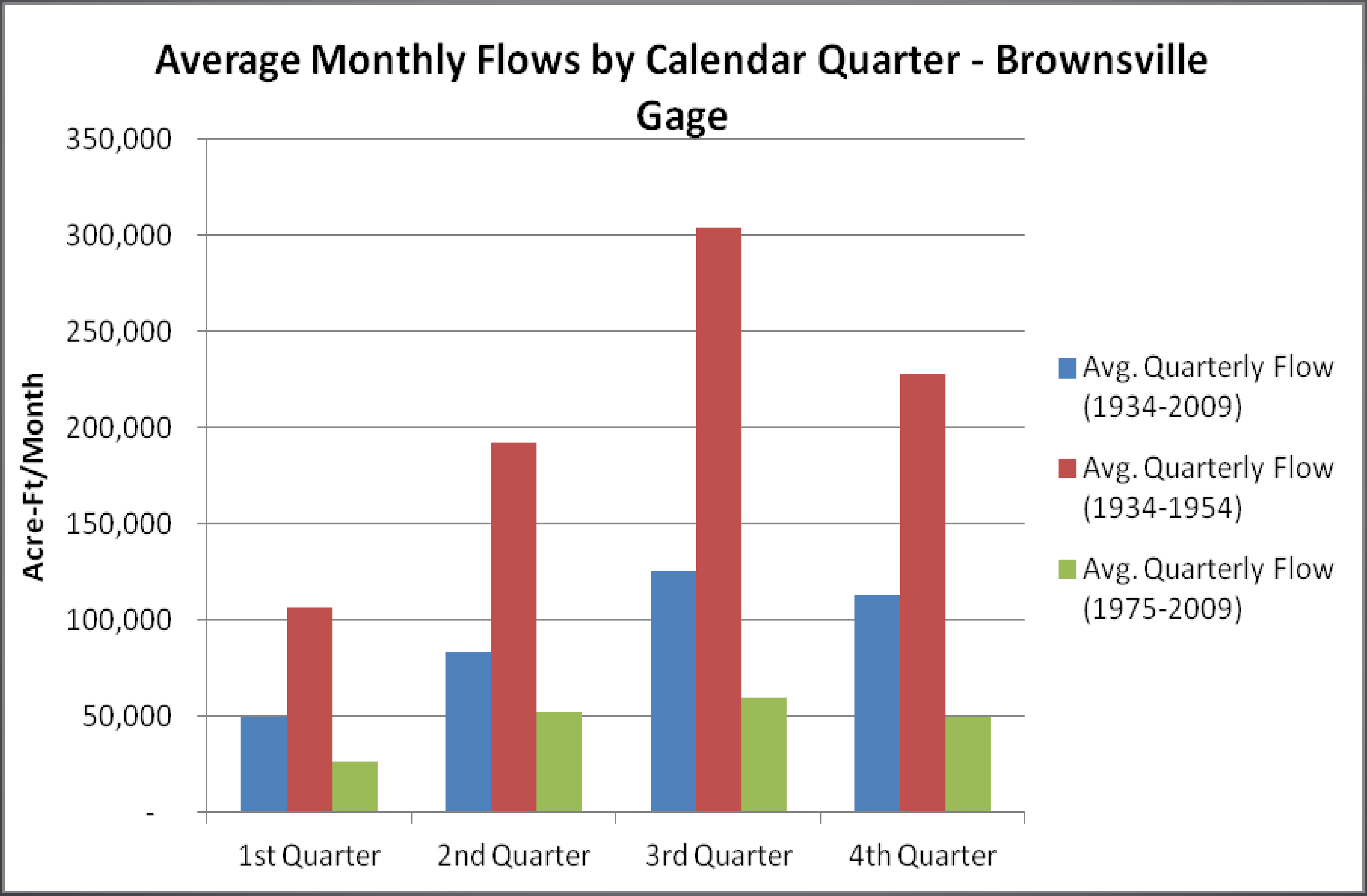


Rio Grande – Brownsville
Average Annual Flows for POR (1934 – 2009)

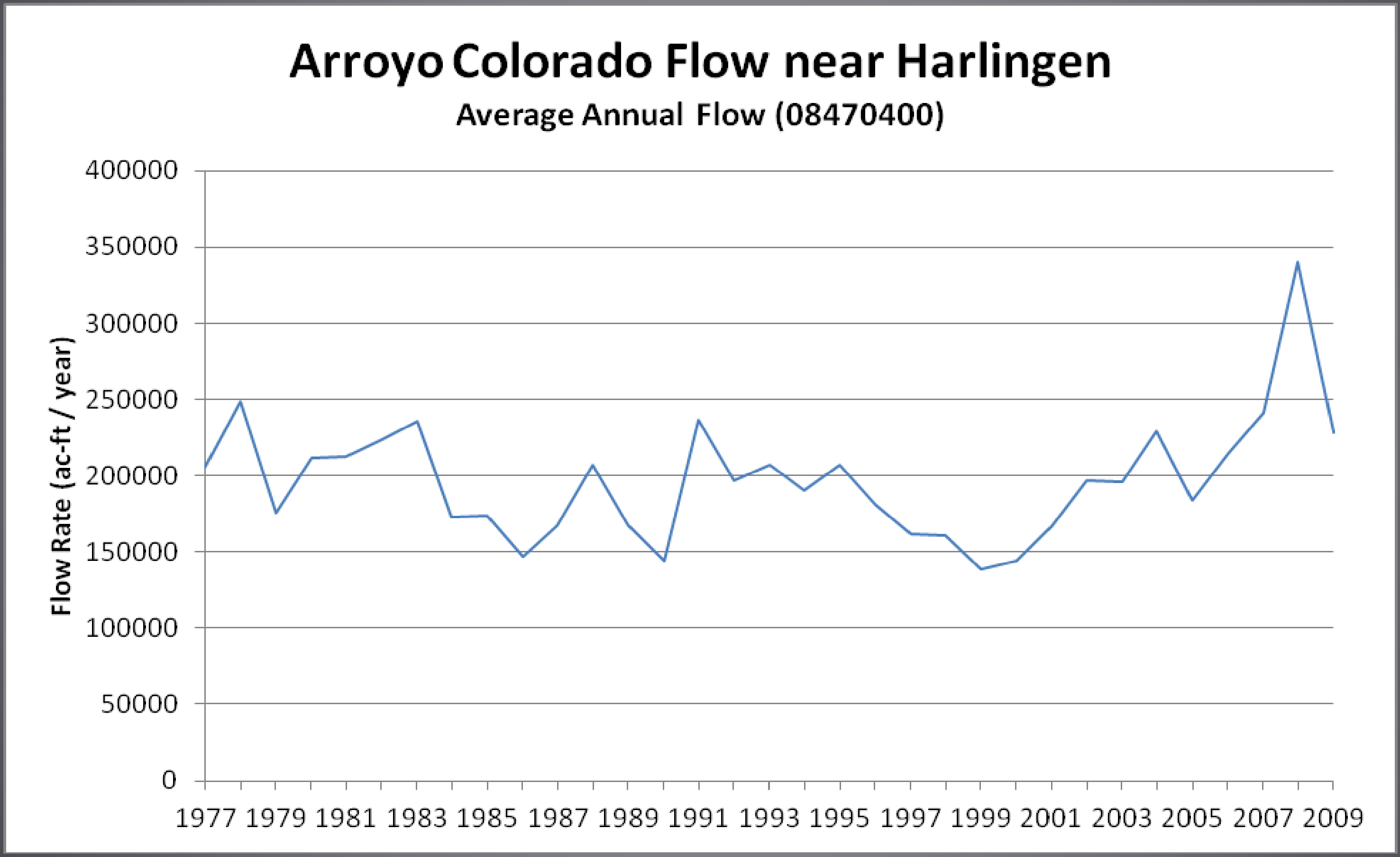


Historic Flows in the Rio Grande					
	Description	**Units**	**Anzalduas Gage (1952-2009)**	**Brownsville Gage (1934-2009)**	**Brownsville Gage (1952-2009)**
Daily Values	**Average Daily Flow**	**(ac-ft/day)**	3,992	3,058	1,692
	Max. Daily Flow	**(ac-ft/day)**	240,272	61,084	32,153
	Min. Daily Flow	**(ac-ft/day)**	0	0	0
Monthly Values	**Average Monthly Flow**	**(ac-ft/month)**	121,249	93,081	51,503
	Max. Monthly Flow	**(ac-ft/month)**	2,326,080	1,427,409	887,393
	Min. Monthly Flow	**(ac-ft/month)**	339	0	0
Yearly Values	**Average Yearly Flow**	**(ac-ft/year)**	1,457,837	1,116,966	618,035
	Max. Yearly Flow	**(ac-ft/year)**	4,640,852	6,524,758	2,645,806
	Min. Yearly Flow	**(ac-ft/year)**	114,748	30,582	30,582

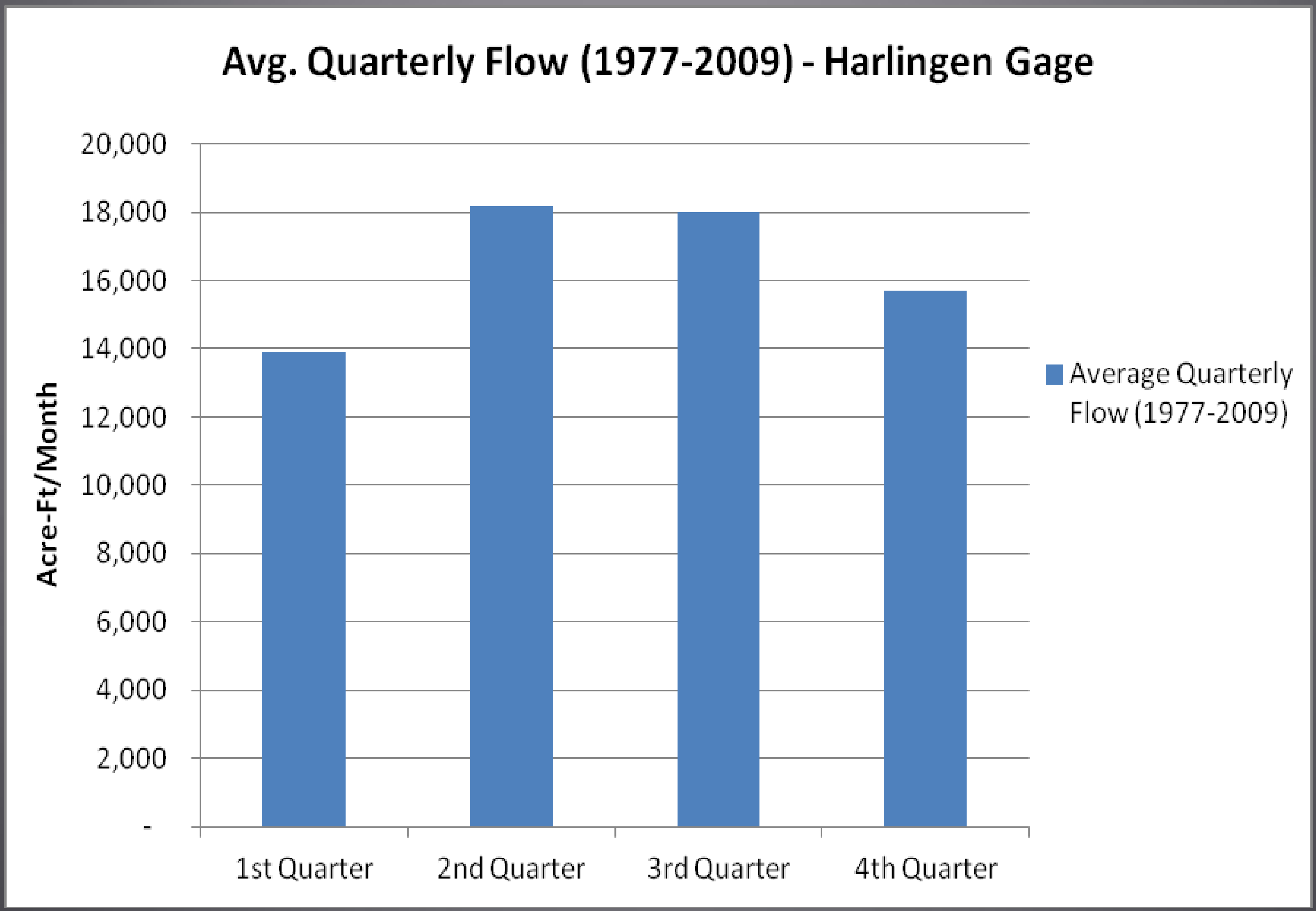
Average Quarterly Flow for Rio Grande at Brownsville Gage (Avg, Older, and Recent PORs)



Arroyo Colorado – Harlingen
Average Annual Flows for POR (1977-2009)



Average Quarterly Flow for Arroyo Colorado at Harlingen Gage (1977-2009)

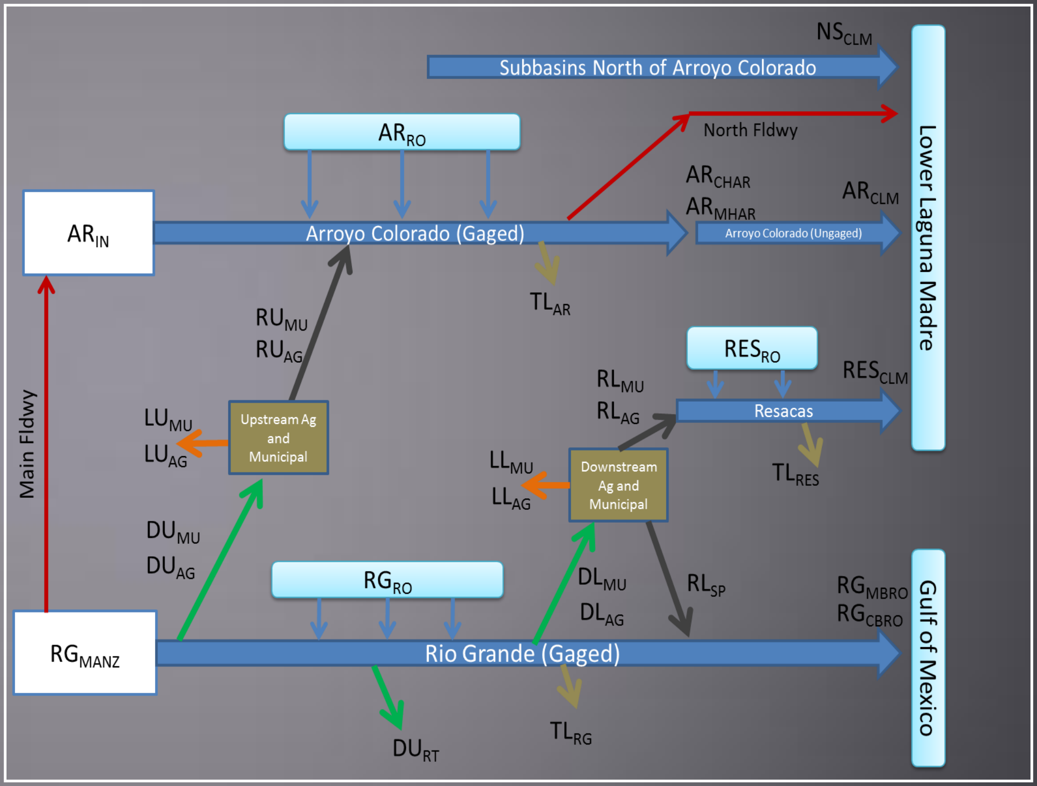


Comparative Percentile Flow Distributions for Common POR (1977-2009)

Monthly Flows - Arroyo Colorado and Rio Grande (1977-2009)			
Percentile	**Harlingen Gage** (1977-2009)	**Anzalduas Gage** (1977-2009)	**Brownsville Gage** (1977-2009)
5th	9,602	26,715	3,179
10th	10,431	34,817	4,177
25th	12,018	51,569	7,131
50th	13,942	81,368	14,533
75th	17,628	129,801	25,550
90th	24,766	191,280	90,403
95th	30,866	283,721	209,117

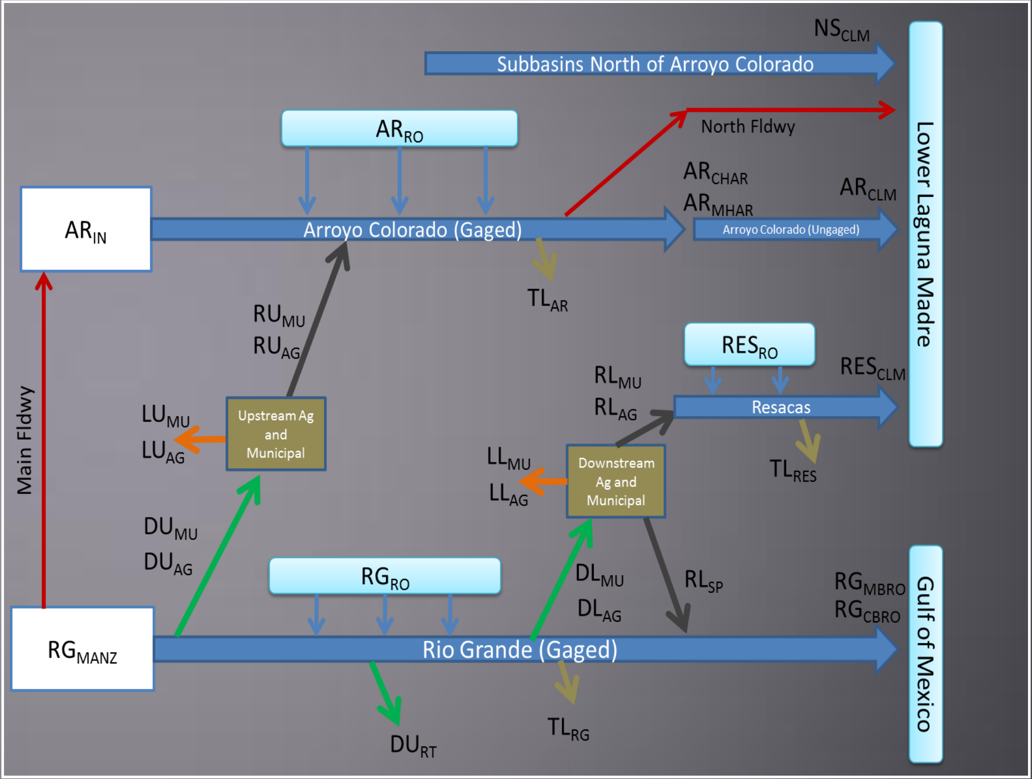
Water Balance and Flow Analysis: Period of Record and Existing Work

- POR was 1999 – 2008
  - Limited by return data
  - SWAT model for Arroyo tremendous aid
- Reliance on TWDB hydrologic study for ungaged basins
  - North Subbasins
  - AC downstream of Harlingen
  - Brownsville / Resacas



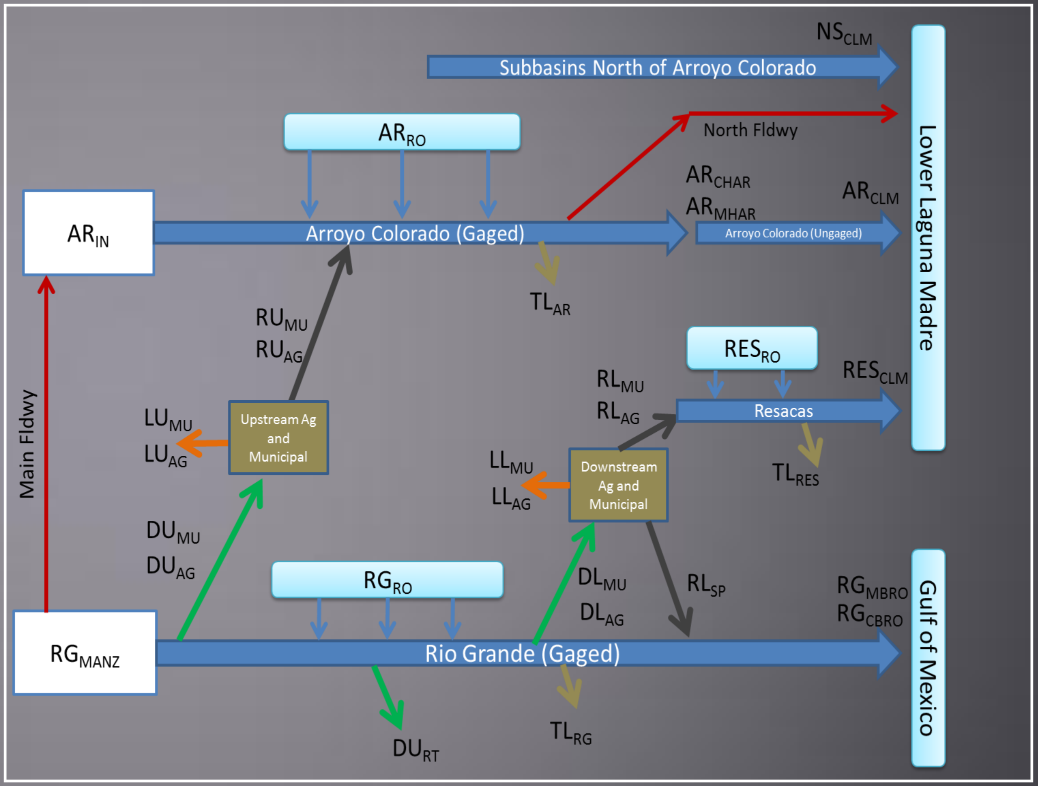
Water Balance and Flow Analysis: Primary Goals

- Primary goals
  - To estimate "natural flow" condition
    - Specific definition
    - Flows without returns and/or diversions
    - Approximated by runoff and losses in stream
  - To estimate component flow at important locations
    - % of flow due to:
      - Agriculture
      - Municipal
      - Runoff



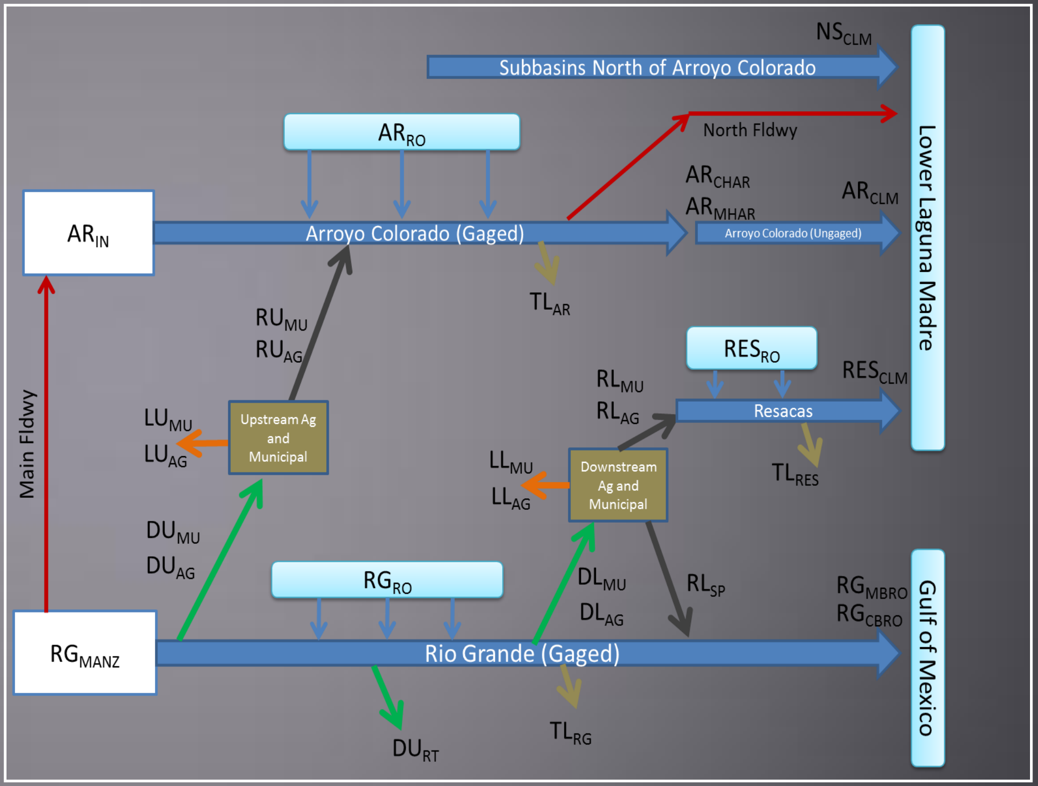
Water Balance and Flow Analysis: Primary Goals (Cont'd)

- Primary goals
  - To provide dataset for development of cumulative distribution function
    - Percentile flow distributions for existing and natural conditions
- Forms the hydrologic basis of flow recommendations



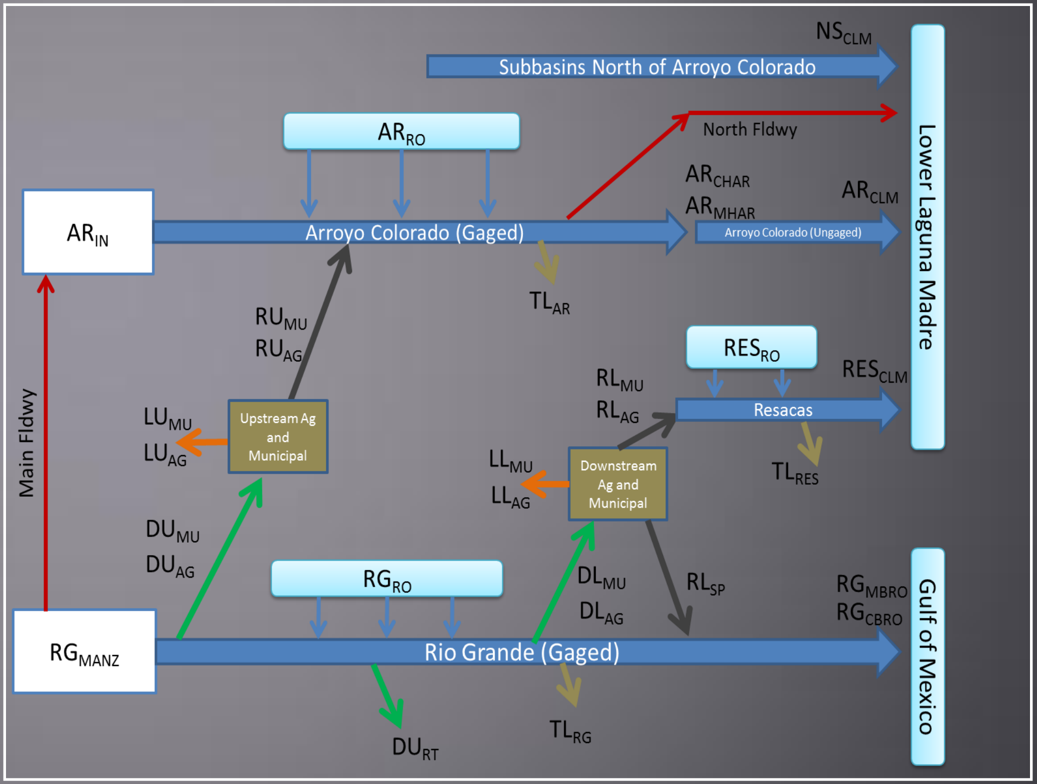
Water Balance and Flow Analysis: Limitations and Caveats

- General balance of:
  - Runoff
  - Agricultural and municipal withdrawals / returns
  - Losses where available
- Specific parameters not investigated:
  - evapotranspiration
  - infiltration
  - groundwater / interflow

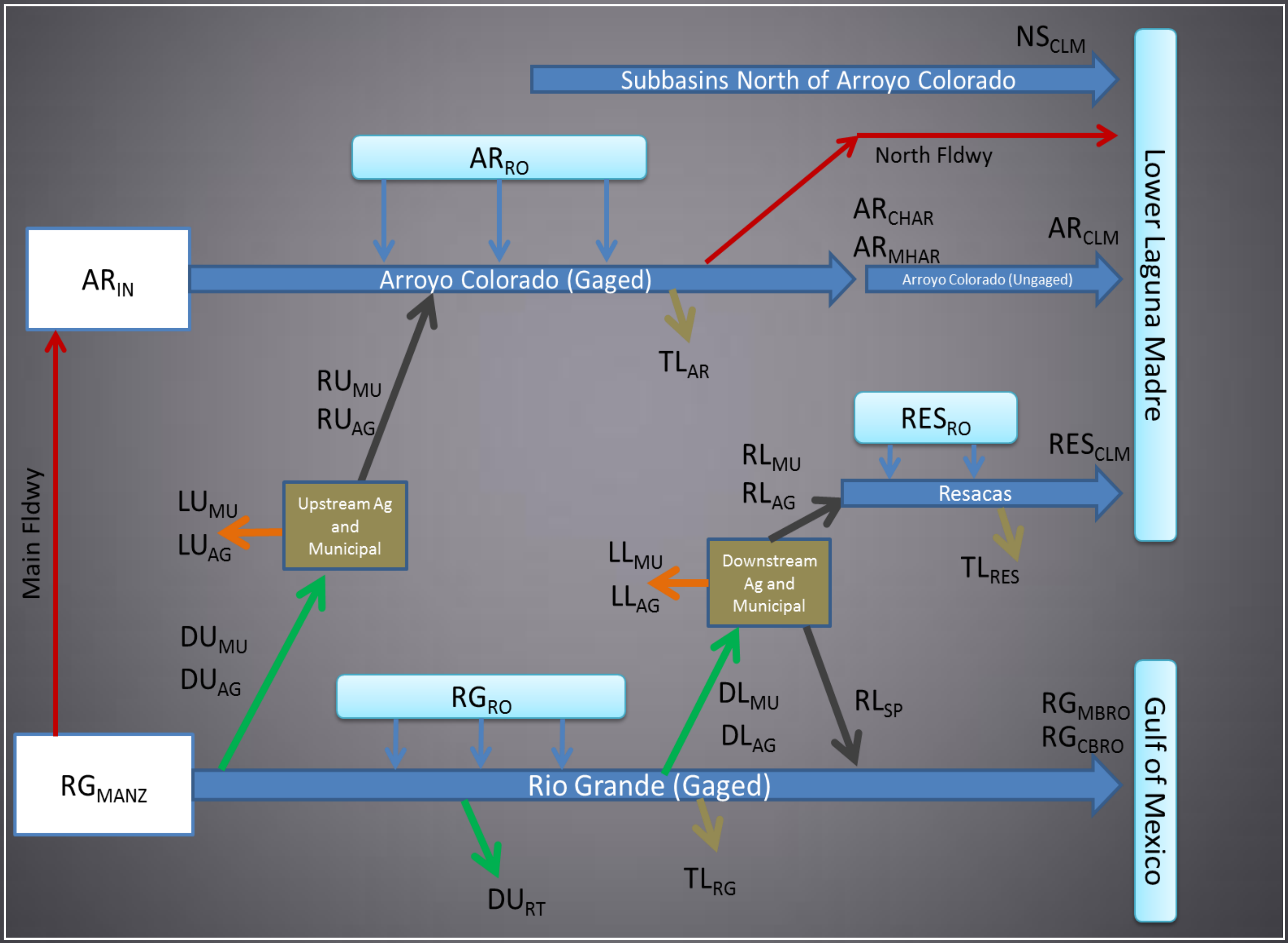


Water Balance and Flow Analysis: Limitations and Caveats

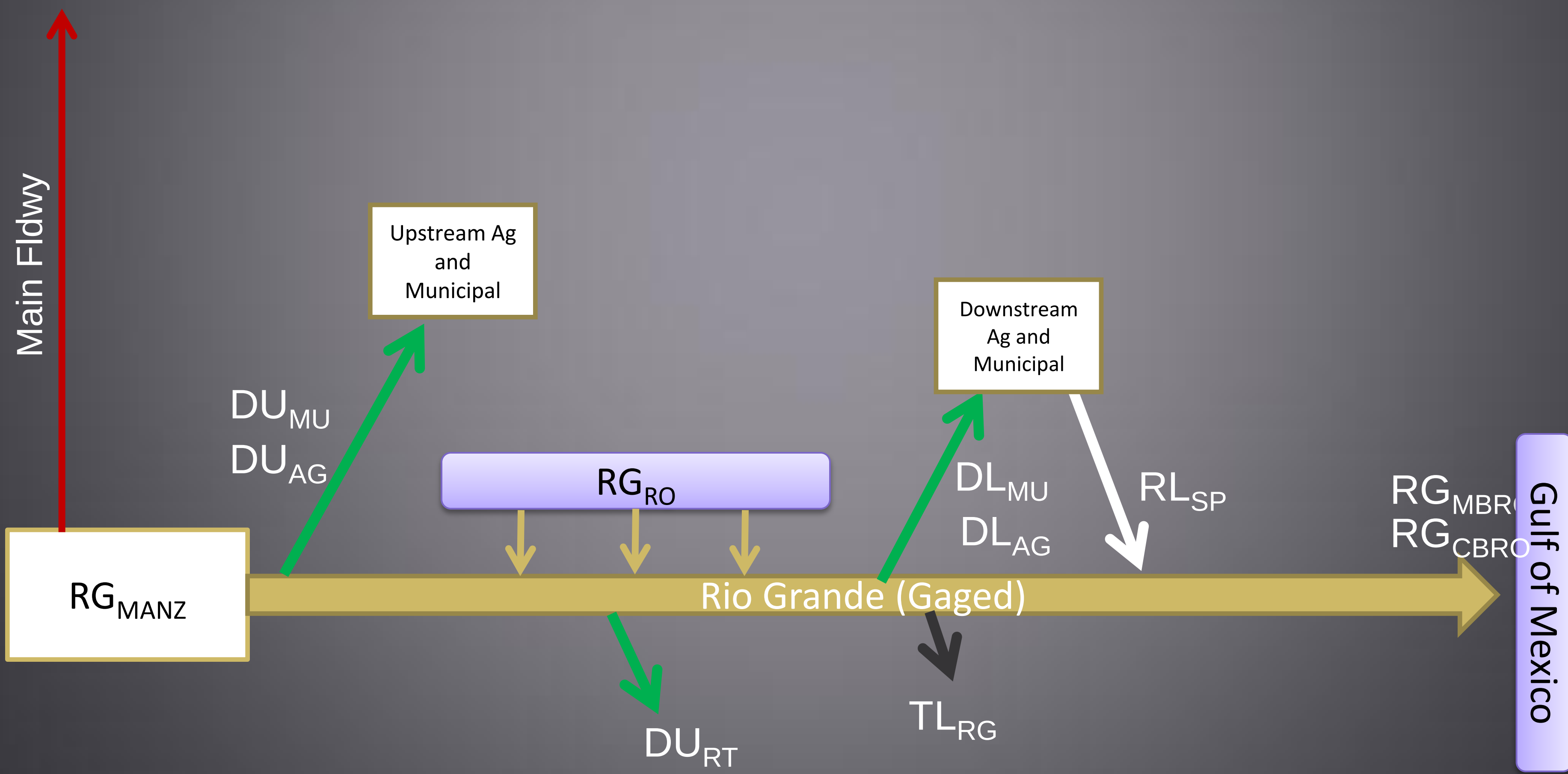
- Additional limitations:
  - No diversion or return data to Mexico
  - POR limited by withdrawal and return data
  - Volumetric flow comparison at monthly time step
  - Not location specific within subwatersheds unless noted
  - Lower Rio Grande Flood Control Project Operations considered outlier events

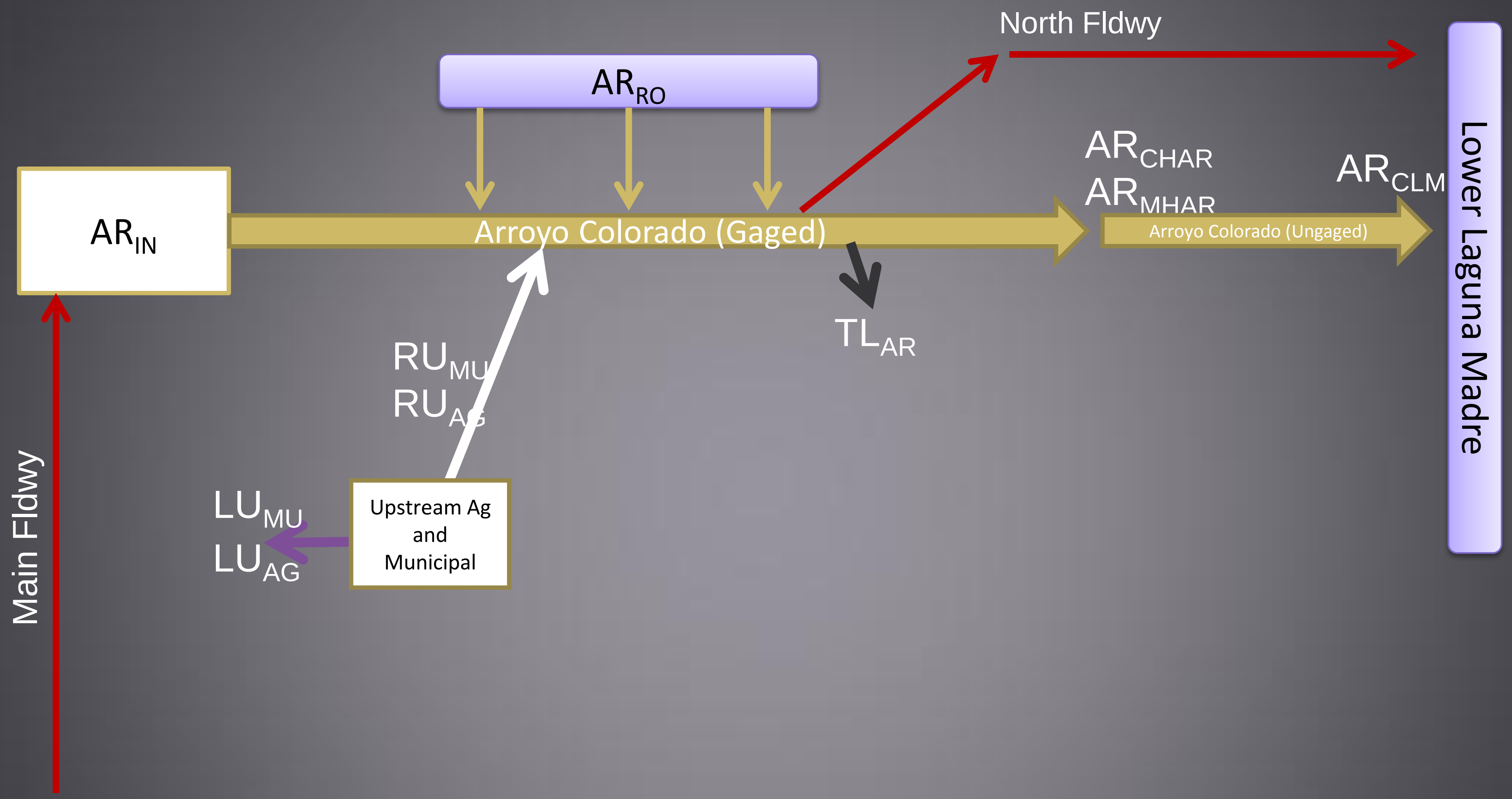


Water Balance Schematic with Variables

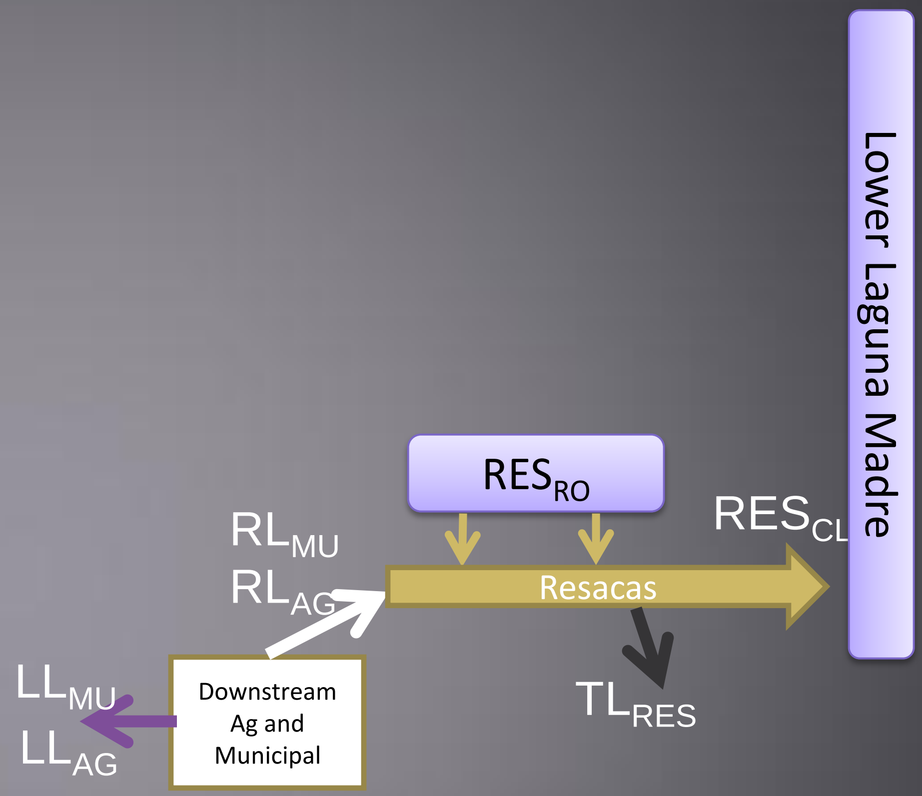


Rio Grande: Inflows and Outflows

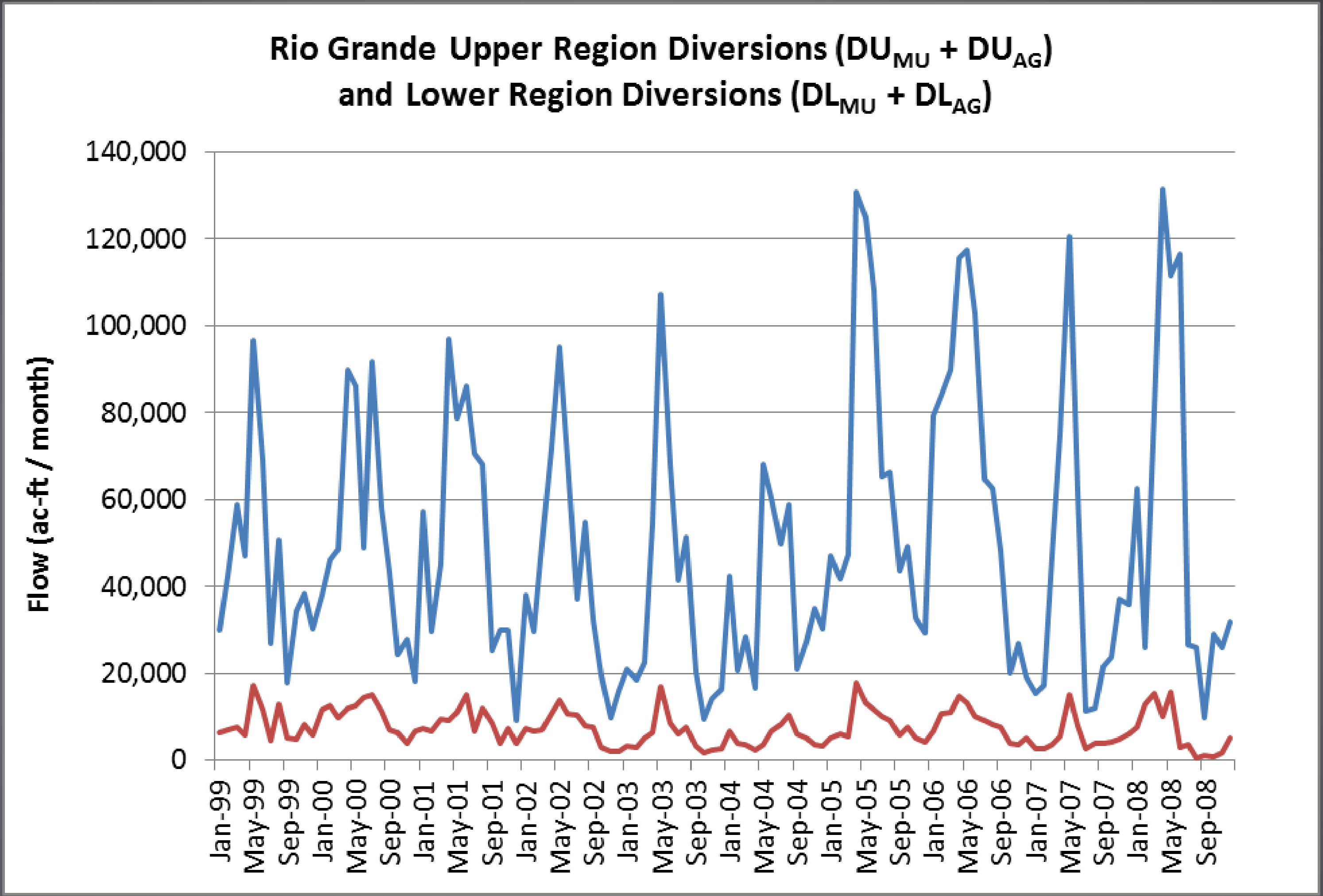




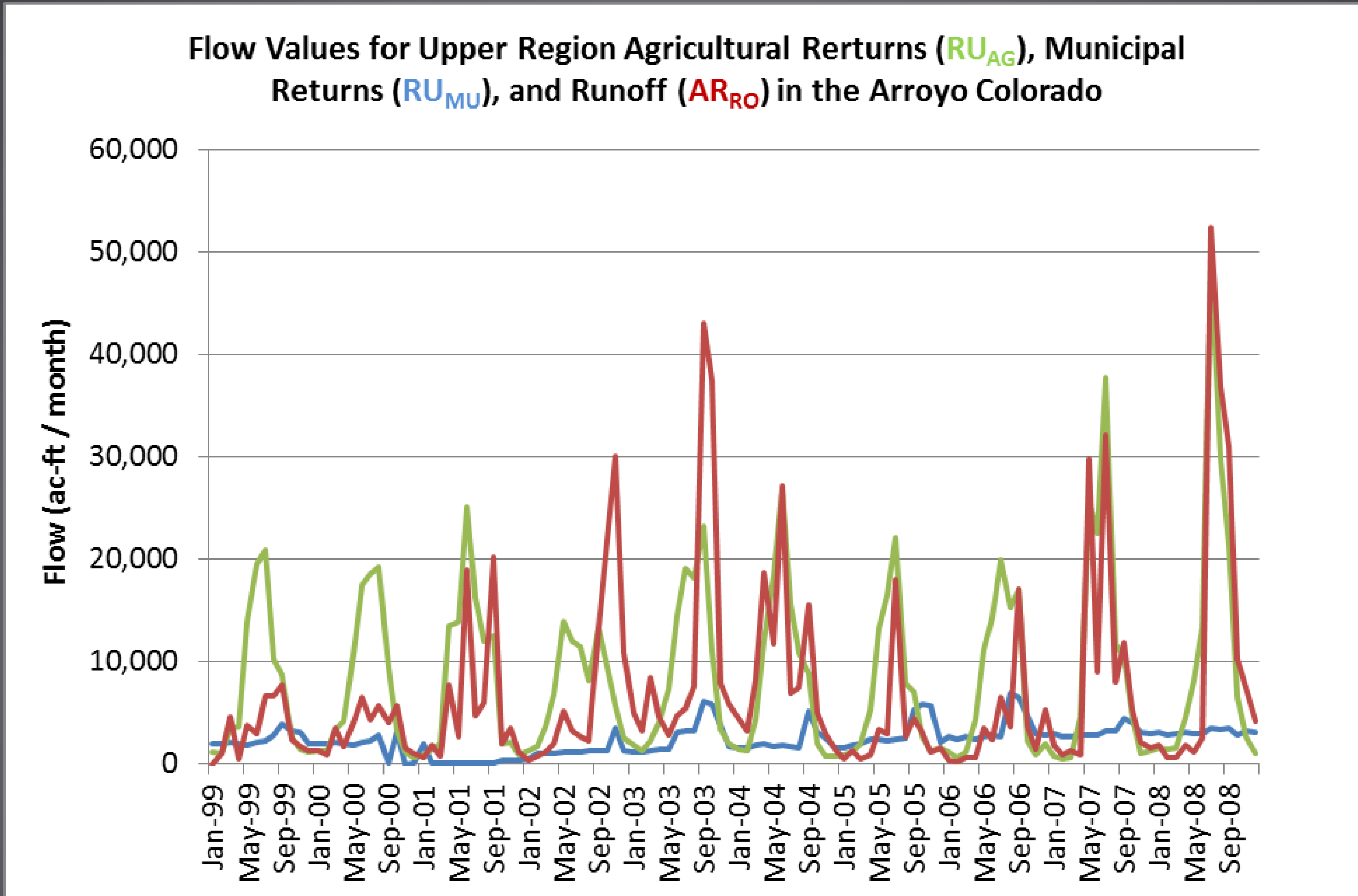
Arroyo Colorado: Inflows and Outflows



Brownsville / Resaca Watersheds: Inflows and Outflows

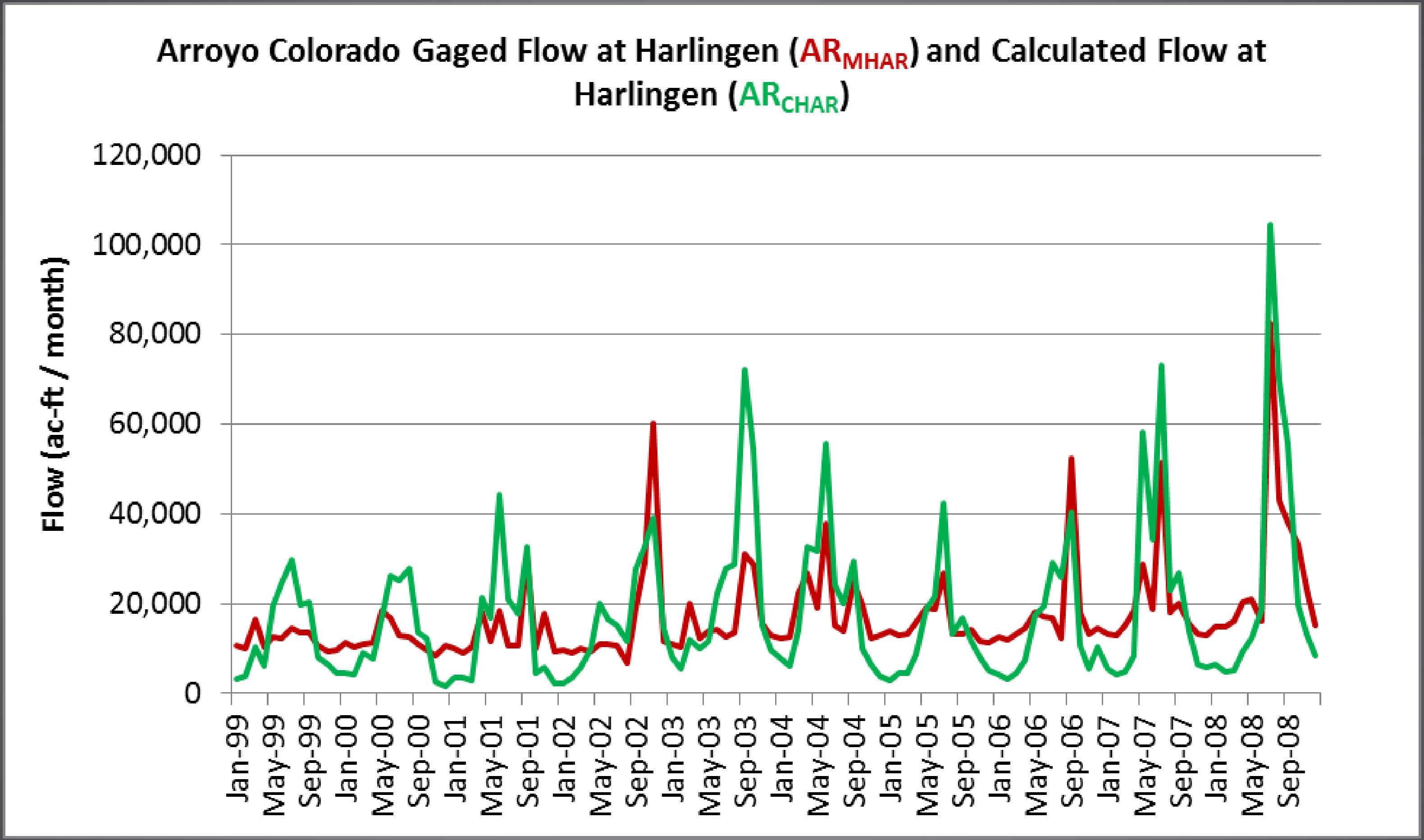


Units: ac-ft / month	DU_{MU} + DU_{AG}	DL_{MU} + DL_{AG}
Average	49,955	7,422
Median	43,002	6,766
Standard Deviation	30,871	4,053

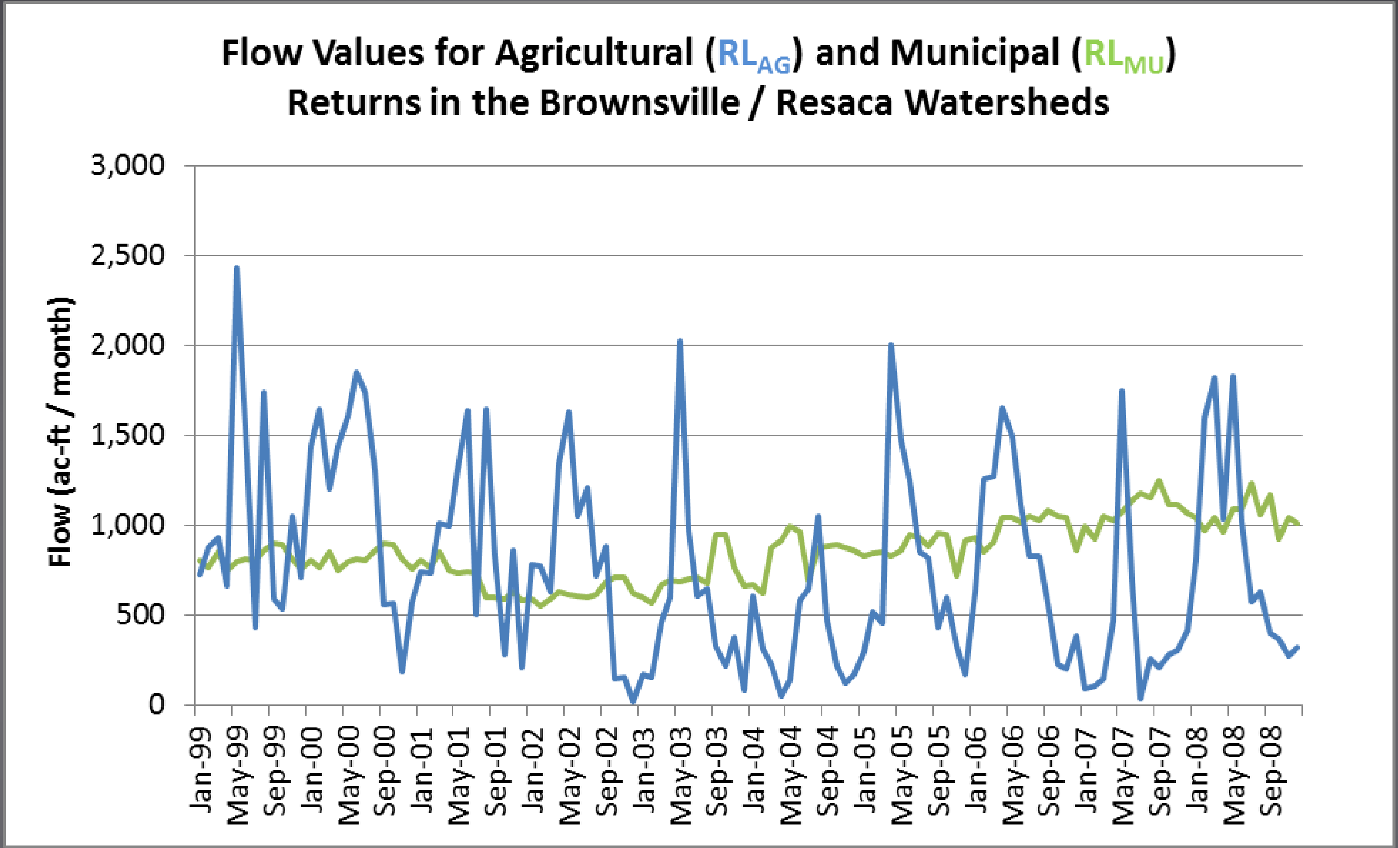


Units: ac-ft / month	RU_{MU}	RU_{AG}	AR_{RO}
Average	2,350	8,464	6,946
Median	2,281	4,569	3,553
Standard Deviation	1,419	8,687	9,536

Annual Average Estimate	% of Flow at Harlingen Gage due to source listed
Agricultural Returns	48%
Municipal Returns	13%
Rainfall Runoff	39%



Units: ac-ft / month	AR_{CHAR}	AR_{MHAR}
Average	17,759	17,112
Median	12,102	13,531
Standard Deviation	17,238	10,763



Units: ac-ft / month	RL_{AG}	RL_{MU}	RL_{SP}	RES_{RO}
Average	773	854	523	4,110
Median	633	857	520	750
Standard Deviation	547	167	51	10,302

Annual Average Estimate	% of Flow in Brownsville / Resaca watersheds due to source listed
Agricultural Returns	13%
Municipal Returns	15%
Rainfall Runoff	72%

Percentile Flows for Subwatersheds based on monthly averages over POR (1999-2008)

	Flows (ac-ft/month)							
	NSclm	NSclmnat	RESclm	RESclmnat	RGmbro	RGcbronat	ARclm	ARclmnat
Min	1,316	928	998	60	1,353	22,507	9,356	153
0.05	1,761	1,288	1,332	127	3,092	31,908	9,932	609
0.1	1,978	1,508	1,414	153	3,661	35,641	10,771	748
0.25	3,065	2,513	1,767	232	7,098	50,094	12,828	1,850
0.5	4,837	3,888	2,496	726	16,703	67,928	15,680	4,273
0.75	11,272	8,693	4,291	2,571	24,857	103,297	21,340	9,092
0.9	29,376	25,802	9,420	8,035	61,810	146,897	36,585	25,323
0.95	43,917	40,525	23,839	22,792	86,608	165,838	55,240	48,905
Max	202,516	179,531	70,273	69,429	257,054	278,043	137,218	106,682
Average	12,077	10,786	5,486	3,979	26,993	81,618	21,102	9,928
Median	4,837	3,888	2,496	726	16,703	67,928	15,680	4,273
St. Dev.	22,989	20,993	9,879	9,972	38,901	46,295	17,412	16,213

Combined Inflow Percentiles to Lower Laguna Madre All Months over POR (1999-2008)

		Existing Inflows to Lower Laguna Madre	Natural Inflows to Lower Laguna Madre	% of Nat Flows / Existing flows
	Units	**(ac-ft/month)**	**(ac-ft/month)**	**%**
Percentile	**Min**	12,313	1,426	11.6%
	0.05	13,997	2,383	17.0%
	0.1	15,649	3,428	21.9%
	0.2	17,736	4,515	25.5%
	0.25	18,441	5,097	27.6%
	0.5	23,654	9,428	39.9%
	0.75	39,962	23,732	59.4%
	0.8	41,291	29,342	71.1%
	0.9	66,732	55,286	82.8%
	0.95	113,411	101,365	89.4%
	Max	393,204	338,325	86.0%
	Average	38,665	24,692	N/A
	Median	23,654	9,428	N/A
	St. Dev.	46,948	43,906	N/A

Combined Inflow Percentiles to Lower Laguna Madre Dry Season Months (November – April) for years 1999-2008

		Existing Dry Season Inflows to Lower Laguna Madre	Natural Dry Season Inflows to Lower Laguna Madre	% of Nat Flows / Existing flows
	Units	**(ac-ft/month)**	**(ac-ft/month)**	**%**
Percentile	**Min**	12,446	1,426	11.5%
	0.05	13,537	1,895	14.0%
	0.1	14,109	2,381	16.9%
	0.2	16,270	3,428	21.1%
	0.25	16,872	3,613	21.4%
	0.5	19,610	5,695	29.0%
	0.75	25,504	12,901	50.6%
	0.8	29,900	15,215	50.9%
	0.9	40,833	28,023	68.6%
	0.95	42,559	30,077	70.7%
	Max	205,357	170,970	83.3%
	Average	26,342	12,669	N/A
	Median	19,610	5,695	N/A
	St. Dev.	25,596	23,087	N/A

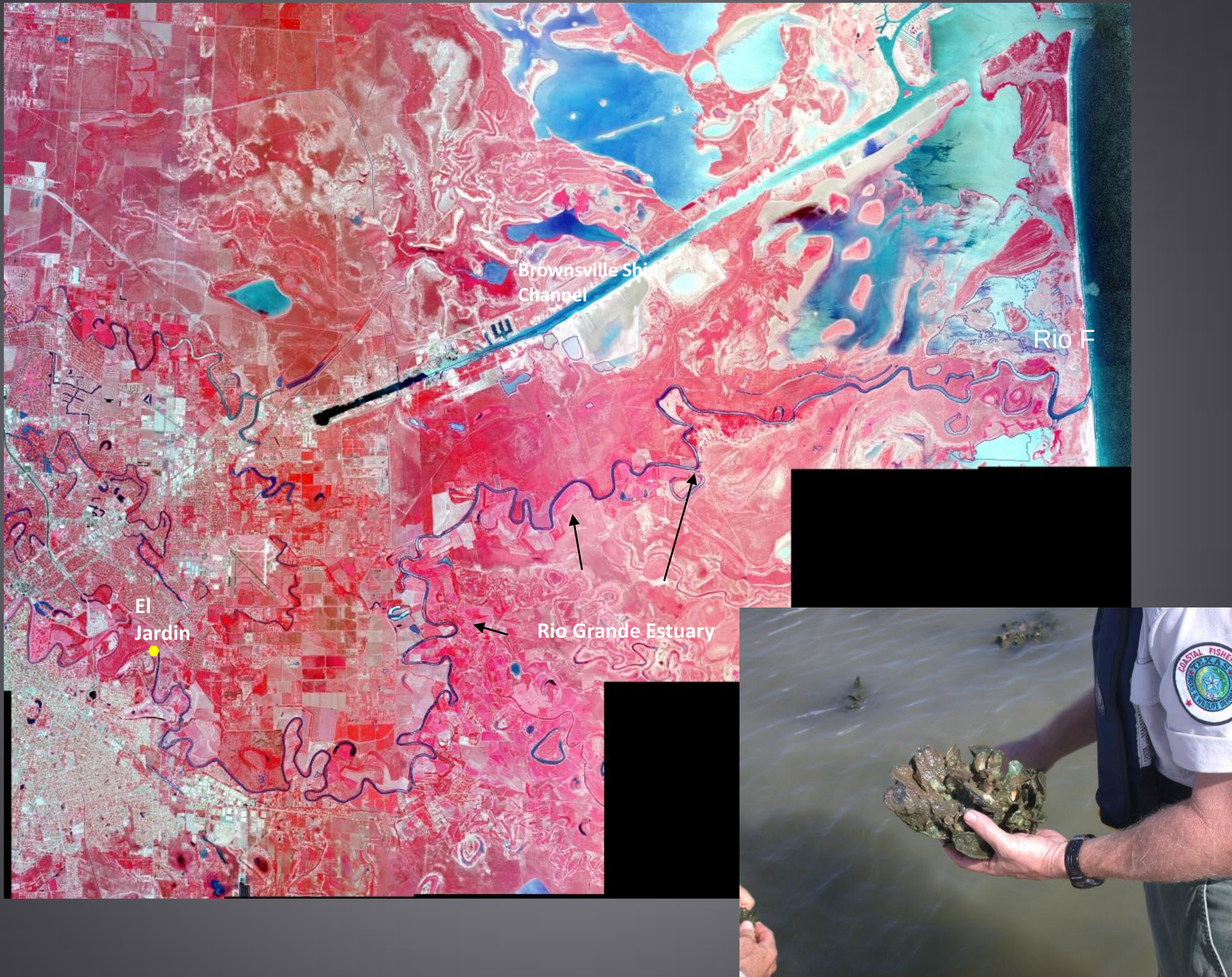
Combined Inflow Percentiles to Lower Laguna Madre Wet Season Months (May – October) for years 1999-2008

		Existing Wet Season Inflows to Lower Laguna Madre	Natural Wet Season Inflows to Lower Laguna Madre	% of Nat Flows / Existing flows
	Units	**(ac-ft/month)**	**(ac-ft/month)**	**%**
Percentile	**Min**	12,313	3,613	29.3%
	0.05	16,386	5,007	30.6%
	0.1	17,743	5,531	31.2%
	0.2	20,909	6,908	33.0%
	0.25	21,214	7,888	37.2%
	0.5	31,213	14,445	46.3%
	0.75	51,620	38,152	73.9%
	0.8	66,072	52,894	80.1%
	0.9	107,042	92,771	86.7%
	0.95	156,861	151,407	96.5%
	Max	393,204	338,325	86.0%
	Average	50,988	36,715	N/A
	Median	31,213	14,445	N/A
	St. Dev.	59,004	55,327	N/A

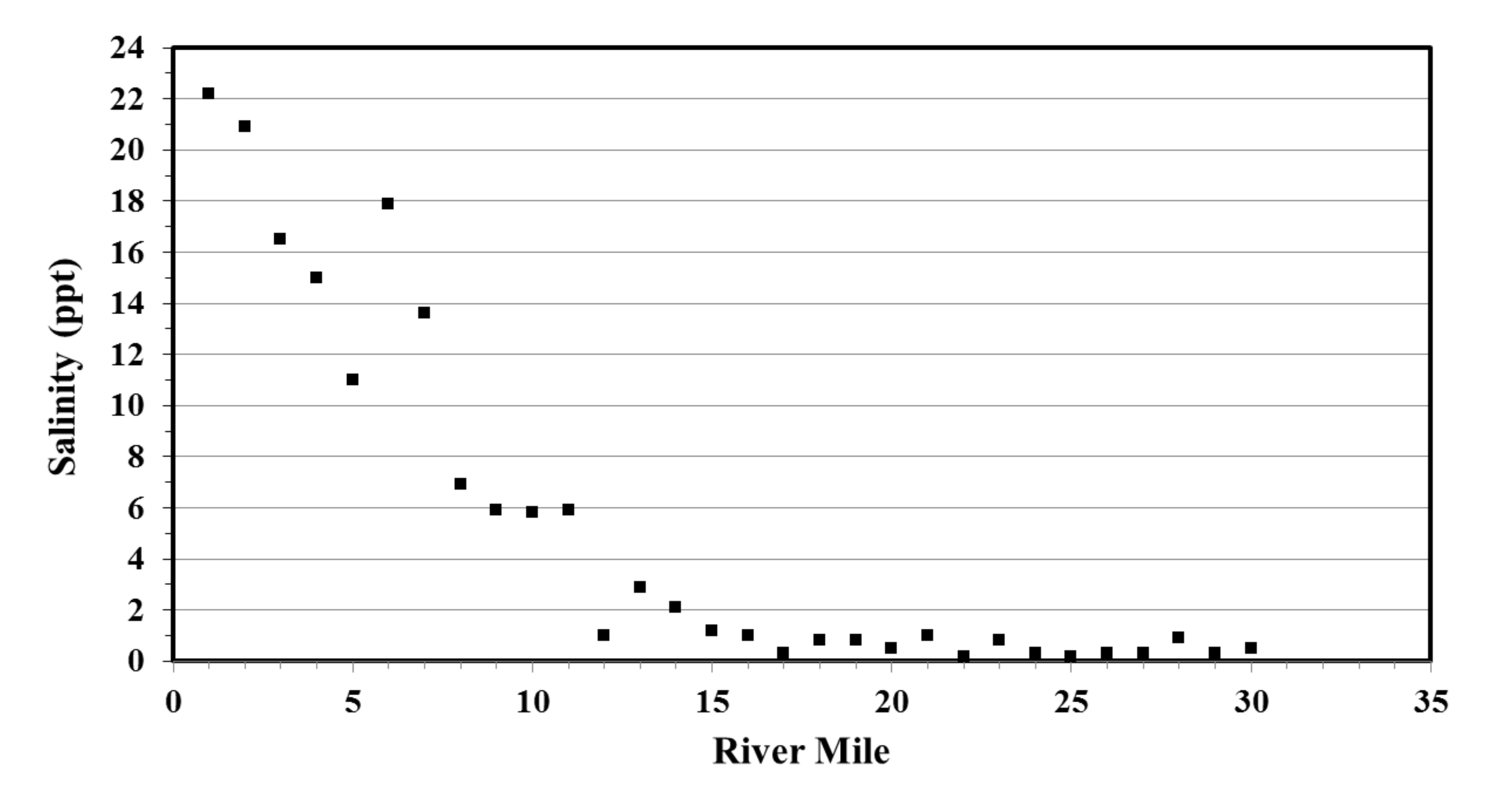
Recommendations for future work on water balance

- Update analysis to include longer period of record
  - Particular emphasis on withdrawal and return data
- Estimate uncertainty in the current deterministic flow values


Tidal Rio Grande

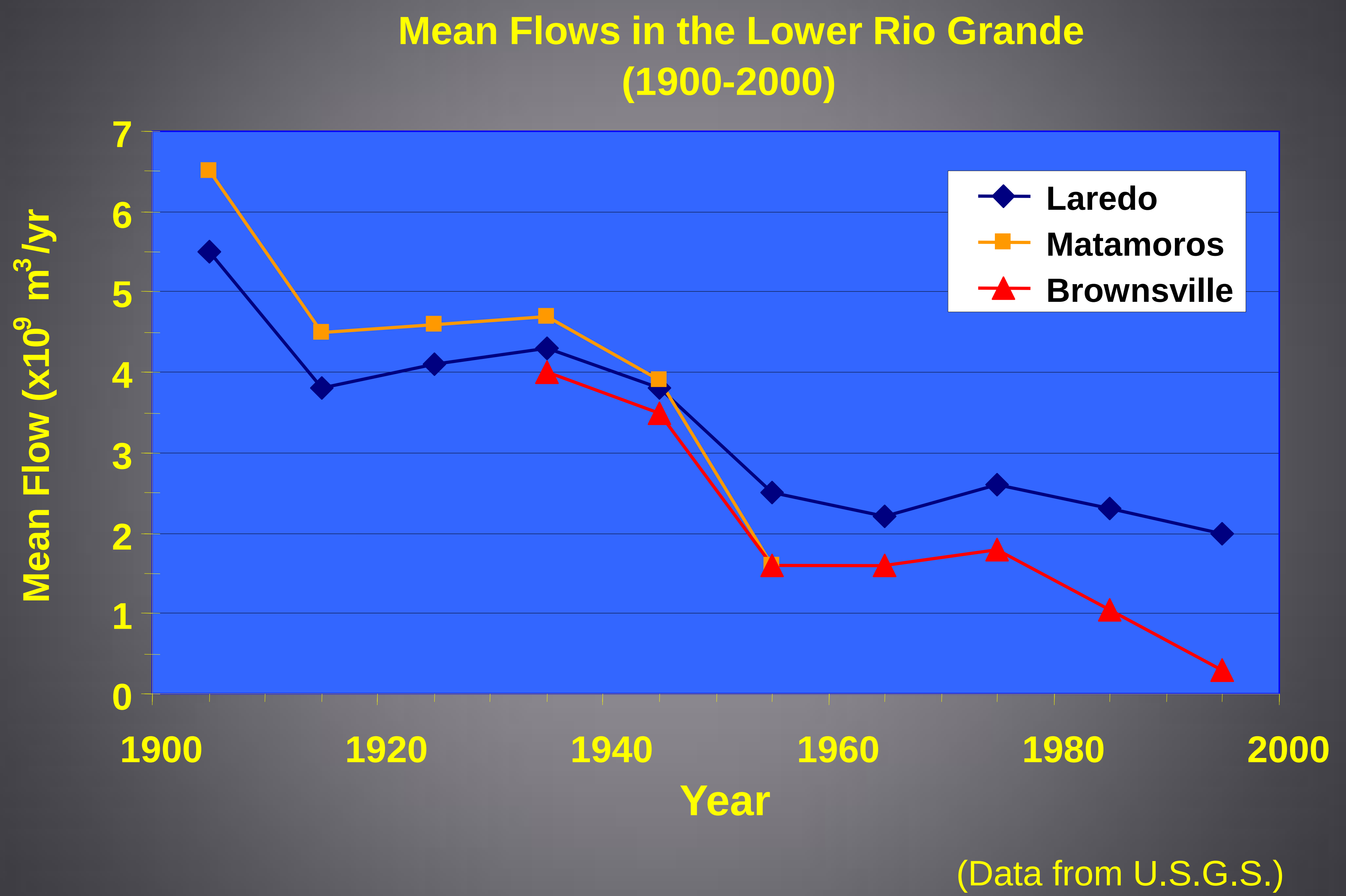

Brownsville Ship Channel
Rio F
El Jardin
Rio Grande Estuary

An Estuarine System



. Bottom salinity along Rio Grande tidal segment, 1992 to1997 (from TPWD, Brownsville, Coastal Fisheries Lab.)





Mean Flows in the Lower Rio Grande
(1900-2000)
Mean Flow (x10^9 m^3/yr
0
1
2
3
4
5
6
7
1900
1920
1940
1960
1980
2000
Year
Laredo
Matamoros
Brownsville
(Data from U.S.G.S.)

Due to a combination of low flow and coastal current conditions the river closed in Feb 2001

July 21, 2001

July 25, 2001

Recommendation #1

- <u>Minimum Flows</u>: Minimum flow of 60 cfs at all times to maintain a salinity transition zone that supports the vegetative communities that transition along the length of the estuary and helps keep the mouth of the river open. It is 25% greater than the 45 cfs identified (Ernest et al. 2007) as necessary to keep the mouth open and it is higher than the average flow of 39 cfs into the tidal reach for the 28 days prior to the mouth closing in February 2001.
- <u>Pulse Flows to Keep the Mouth Open</u>: Daily average flow of 175 cfs at least once every 2 months (based on flows during 1999, which had lower total inflow than all but one other year during the period of record from 1934 to 2010), when there were 7 pulse periods with at least one day of daily average flow exceeding 175 cfs.
- <u>Daily Average Flows</u>: Daily average flow of 880 cfs at least once each year (based on the November 3, 2002 flow of 915 cfs which was part of a wet period that helped naturally reopen the river mouth by November 7, 2002). No pulse flows of this magnitude occurred from February 4, 2001 through November 3, 2002, during which period the river mouth was closed (except when artificially opened in late July 2001).

Recommendation #2

- Hydrologic stream flow data documents the highly pulsed, episodic nature of inflows to the estuary (IBWC 2010). Under very reduced flows, this could produce excessive salinity levels in the upper reaches of the estuary and create unnatural conditions for the ecological functioning of this part of the ecosystem.
- City of Brownsville Water Permit for the Brownsville-Matamoros Weir contains a flow restriction for water diversion at the El Jardin site.
- When salinity rises to a value of 2,250 uS cm^{-1} at river mile 23.6, then water cannot be diverted unless flows are 25 cfs or higher. This salinity level is the highest value recorded in recent years during extremely low flow periods, which were reached when the river mouth became plugged.
- In a recently completed monitoring study over the period 2000-2009 (Machin 2009), it was shown that low river flows will produce these elevated bottom salinities at mile 23.6; thus diversions at El Jardin would need to be curtailed at even higher flows than 25 cfs. The BBEST recommends maintaining this 25 cfs flow minimum, but cautions that an even higher flow threshold could be necessary as a result of further monitoring and data analysis.

Freshwater Inflows Analysis for Lower Laguna Madre

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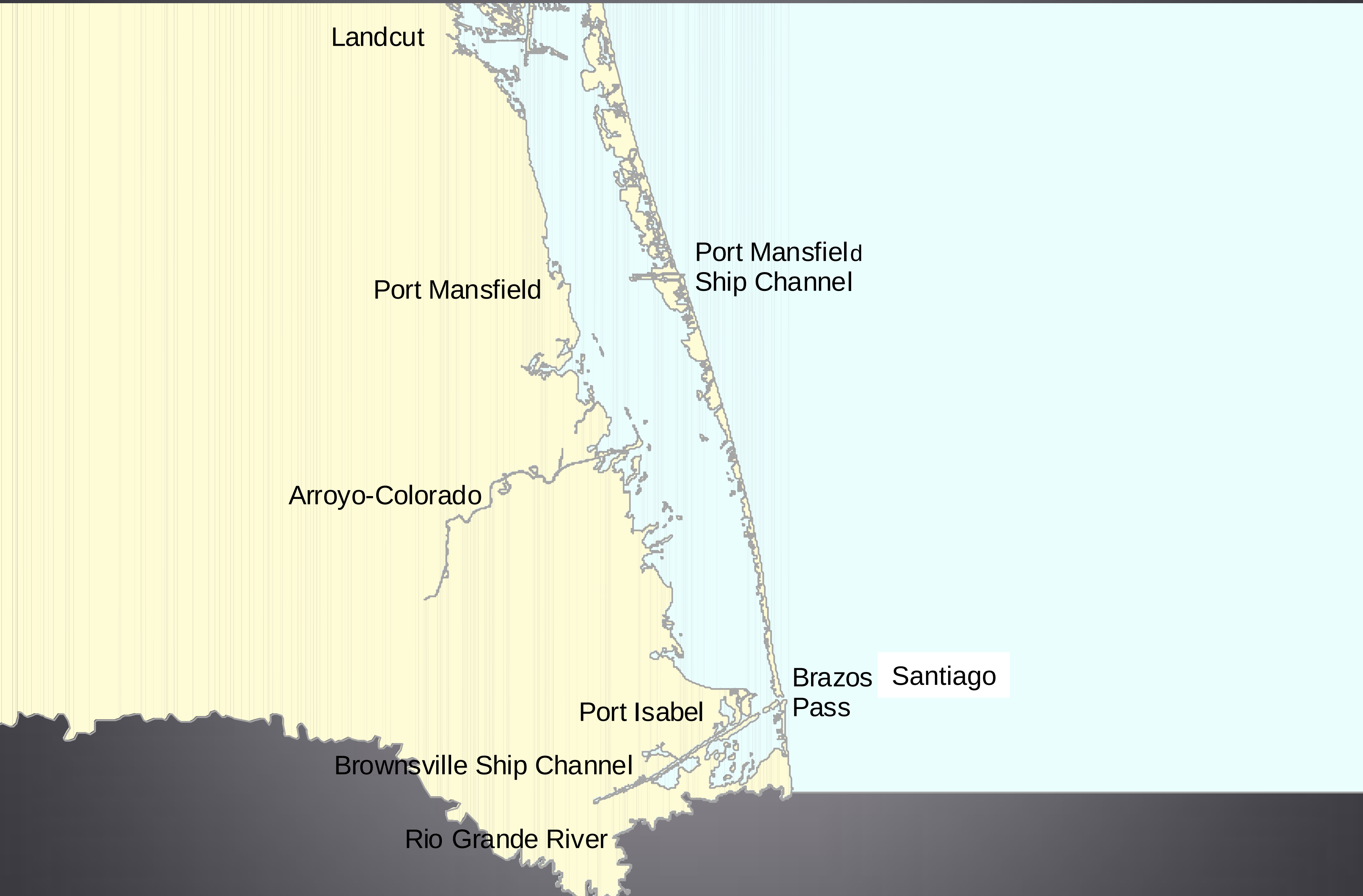
Dave Buzan, MS
Warren Pulich, PhD
Robert Edwards, PhD
Jude Benavides, PhD
Carlos Marin, PE

July 18, 2012

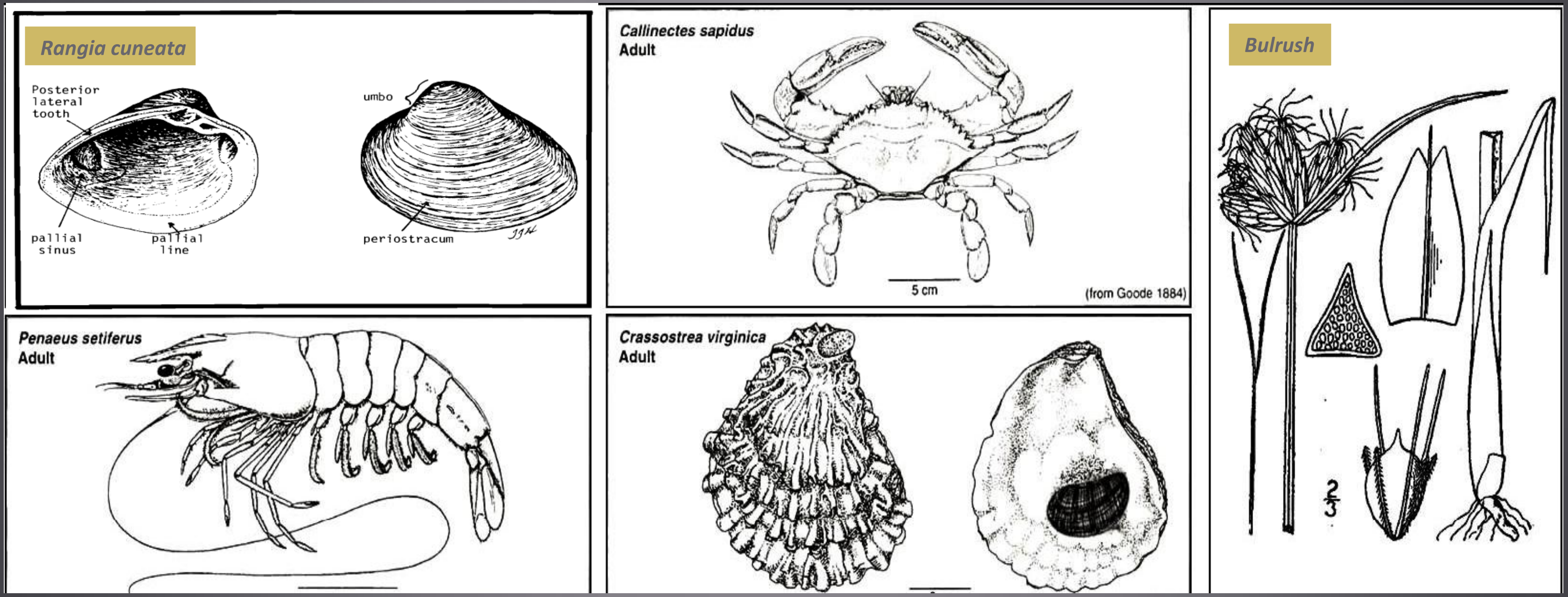

Landcut
Port Mansfield
Ship Channel
Port Mansfield
Arroyo-Colorado
Brazos
Santiago
Pass
Port Isabel
Brownsville Ship Channel
Rio Grande River

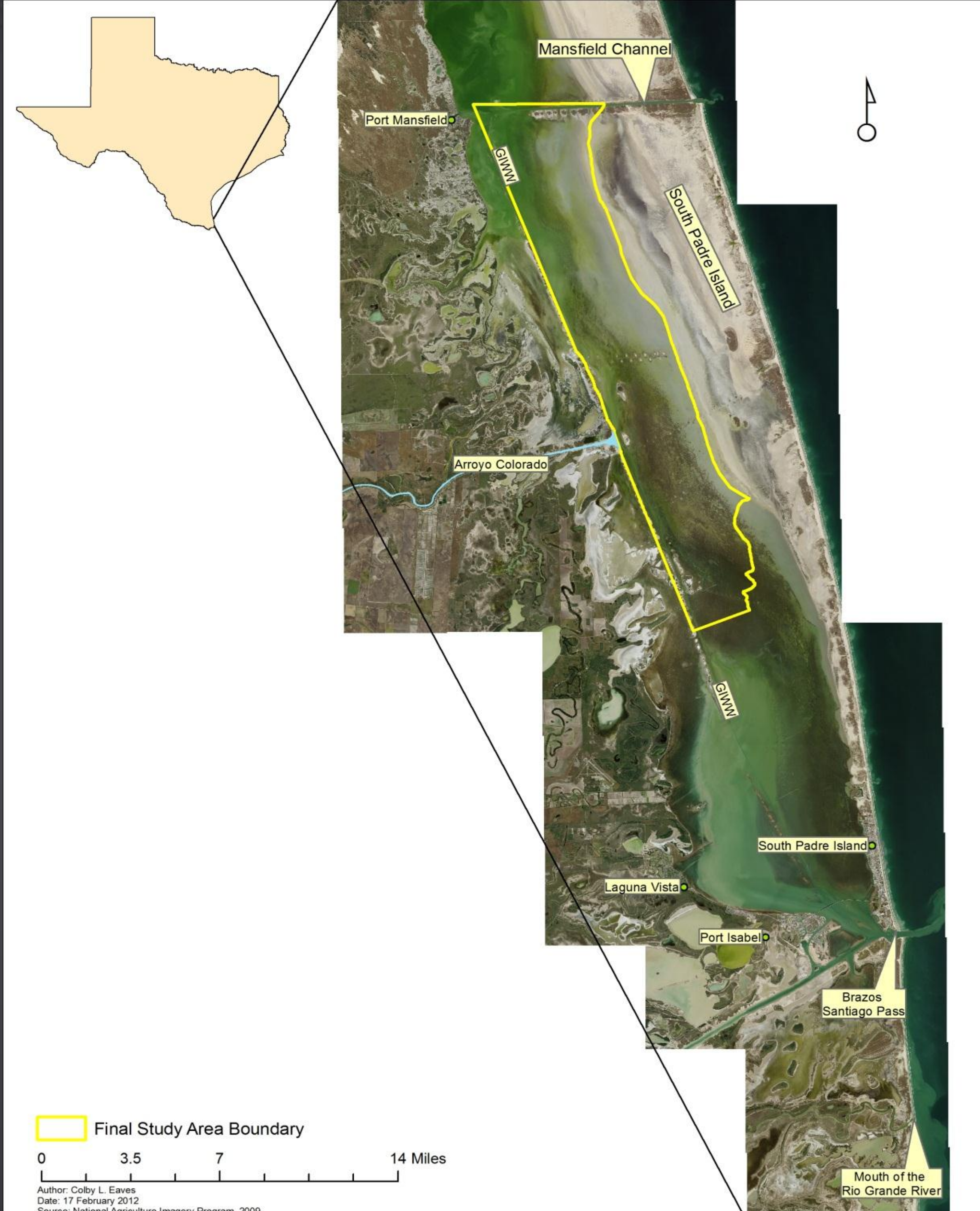
LLM Freshwater Inflow Analyses

1) Focal Species: Seagrass Habitat Changes
2) FWI Effects on Lower Laguna Madre Seagrasses?
3) Hydrologic Record Analysis
4) Freshwater Inflow Plumes as Proxy for Water Quality Impacts?
5) Identify Inflow Regime Thresholds for Seagrass
6) Develop Environmental Flow Recommendations

Estuarine Focal Species

Sessile vs. Motile Species and Responses to FWIs





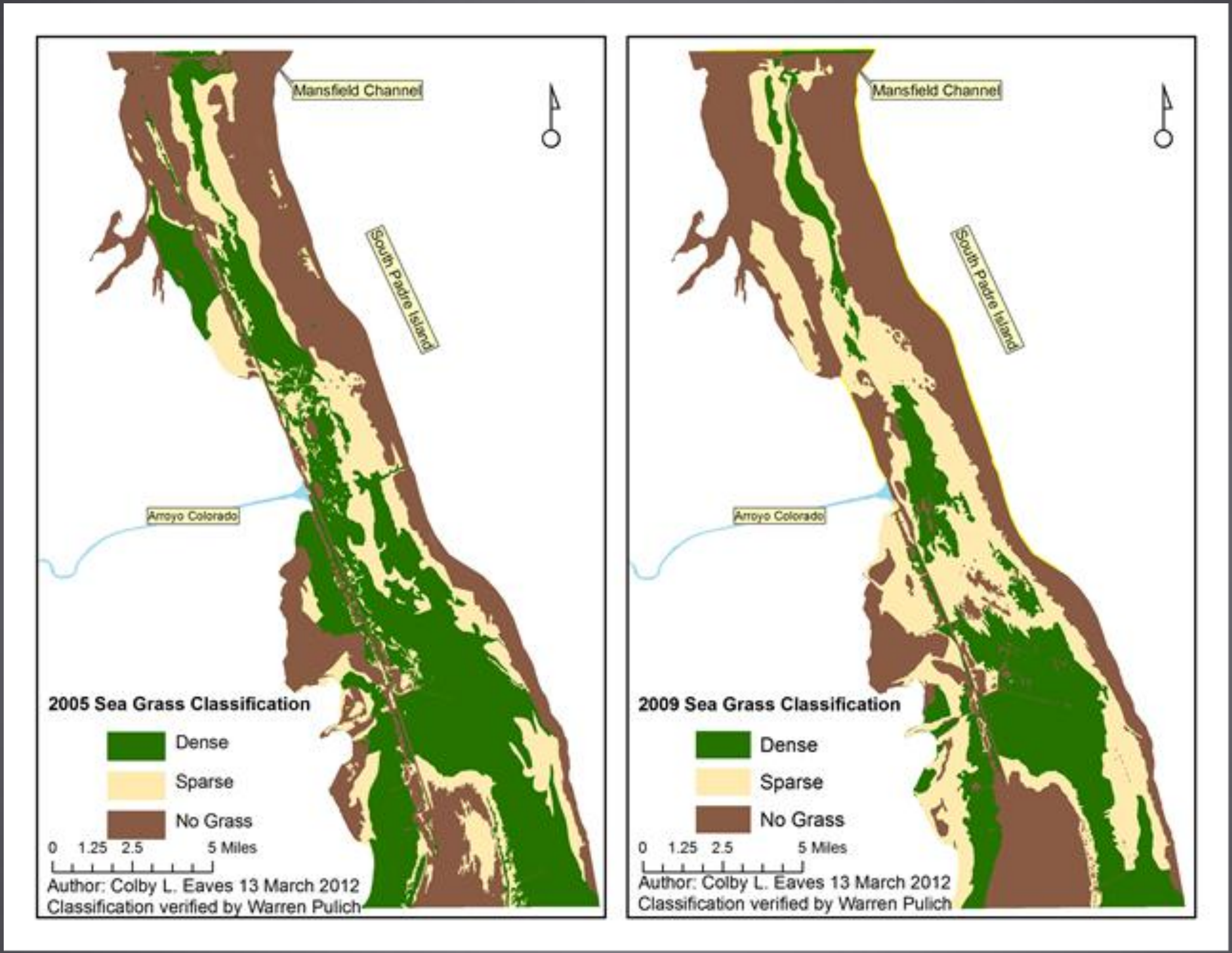
2009 NAIP Imagery
of Lower Laguna Madre:

Seagrass Distribution and Species Composition

LLM Seagrass Communities

LLM Seagrass Communities

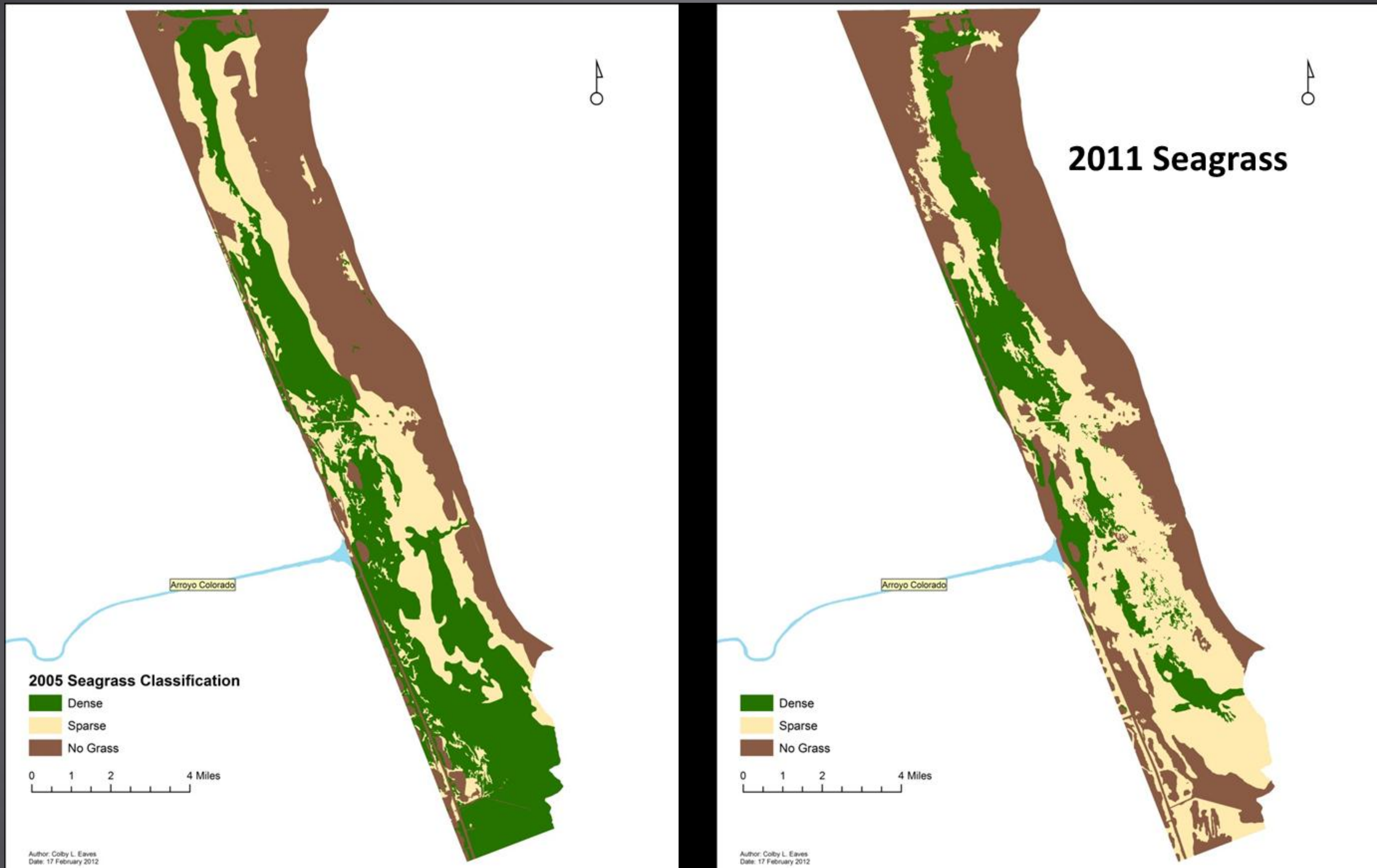
Seagrass Responses to Salinity and/or Nutrients



Seagrasses Mapped in 2005 and 2009

Change in Seagrass Acreage between 2005 – 2009

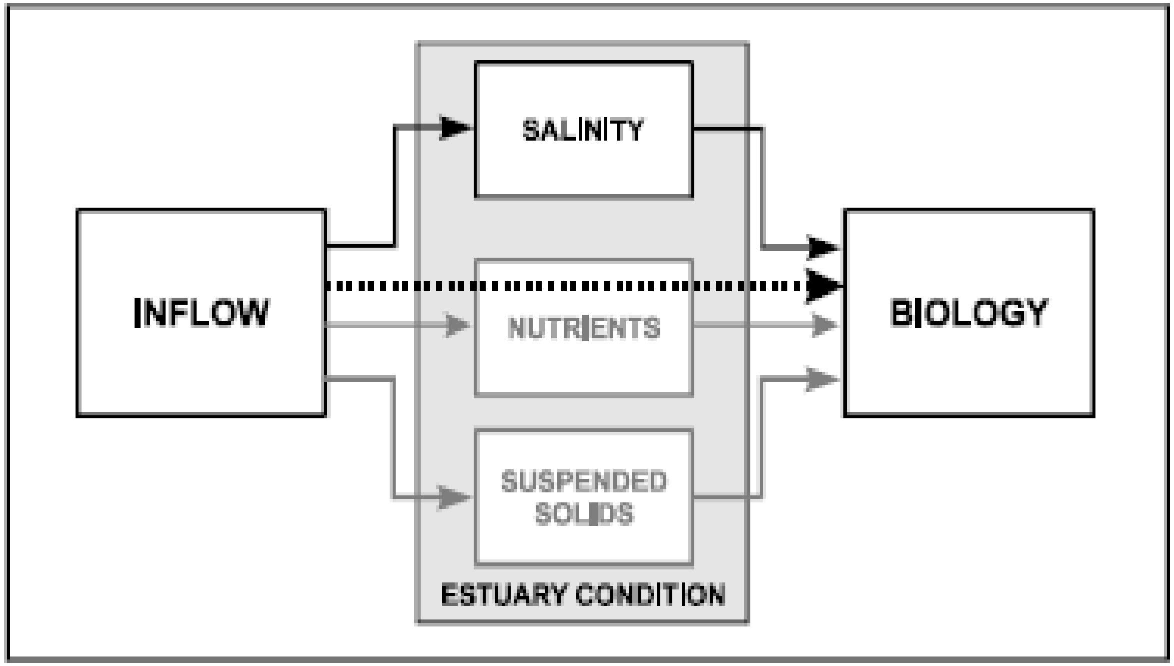
	Nov. 2005 USACE		Jan. 2009 NAIP	
	Acres	% area	Acres	% area
Dense Grass	39,134	40.6	24,067	25.0
Sparse Grass	21,532	22.3	29,784	30.9
Bare Area	35,782	37.1	42,605	44.2
TOTAL	96,448	100	96,456	100



Seagrasses Mapped in 2005 and 2011

Change in Seagrass Acreage between 2005 - 2011

	Nov. 2005		Oct. 2011	
	Acres	% area	Acres	% area
Dense Grass	18,453	37.9	9,324	18.3
Sparse Grass	11,946	24.5	16,748	35.1
Bare Area	18,289	27.6	22,614	46.6
TOTAL	48,689	100	48,689	100



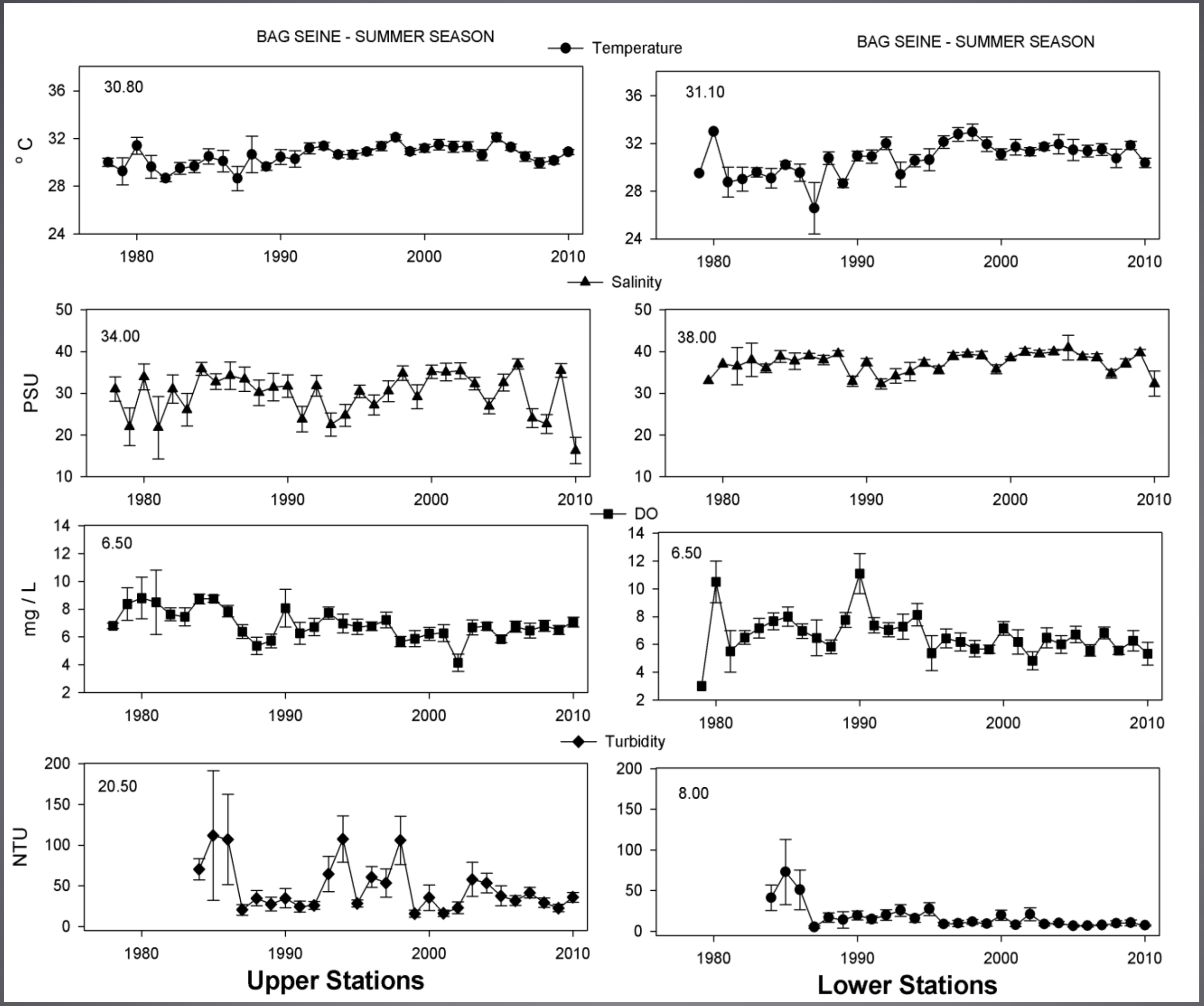
SAC

Figure 2.1-2 – Schematic of Relation of "Biology" to "Inflow"
(Compressed from Figure 2.2-1)

Effects of Freshwater Inflow on Estuarine Ecosystems

Salinity Tolerance Ranges of LLM Seagrasses

Seagrass Species	Optimal Growth Salinity Range (psu)	Lethal Salinity Range (psu)
Shoal grass (Halodule wrightii)	20 – 44	6 or <; 70 or >
Clover or star grass (Halophila engelmannii)	23 – 40	13 or <; 50 or >
Turtle grass (Thalassia testudinum)	24 – 38	10 or <; 48 or >
Manatee grass (Syringodium filiforme)	24 – 38	10 or <; 44 or >



Lower Laguna Madre Hydrographic Conditions

Hydrology Analyses

1) Geographic Scope (Lower Laguna Madre and its subwatersheds)
2) Flow Regime Period of Record (1977 - 2010)
3) Gage Selection (Arroyo Colorado @ Harlingen)
4) Ungaged Watersheds for LRGV
5) Gaged vs. Ungaged Inflows to LLM

Coastal Hydrology

Version TWDB201101-L

Gaged

+ Modeled (Ungaged)

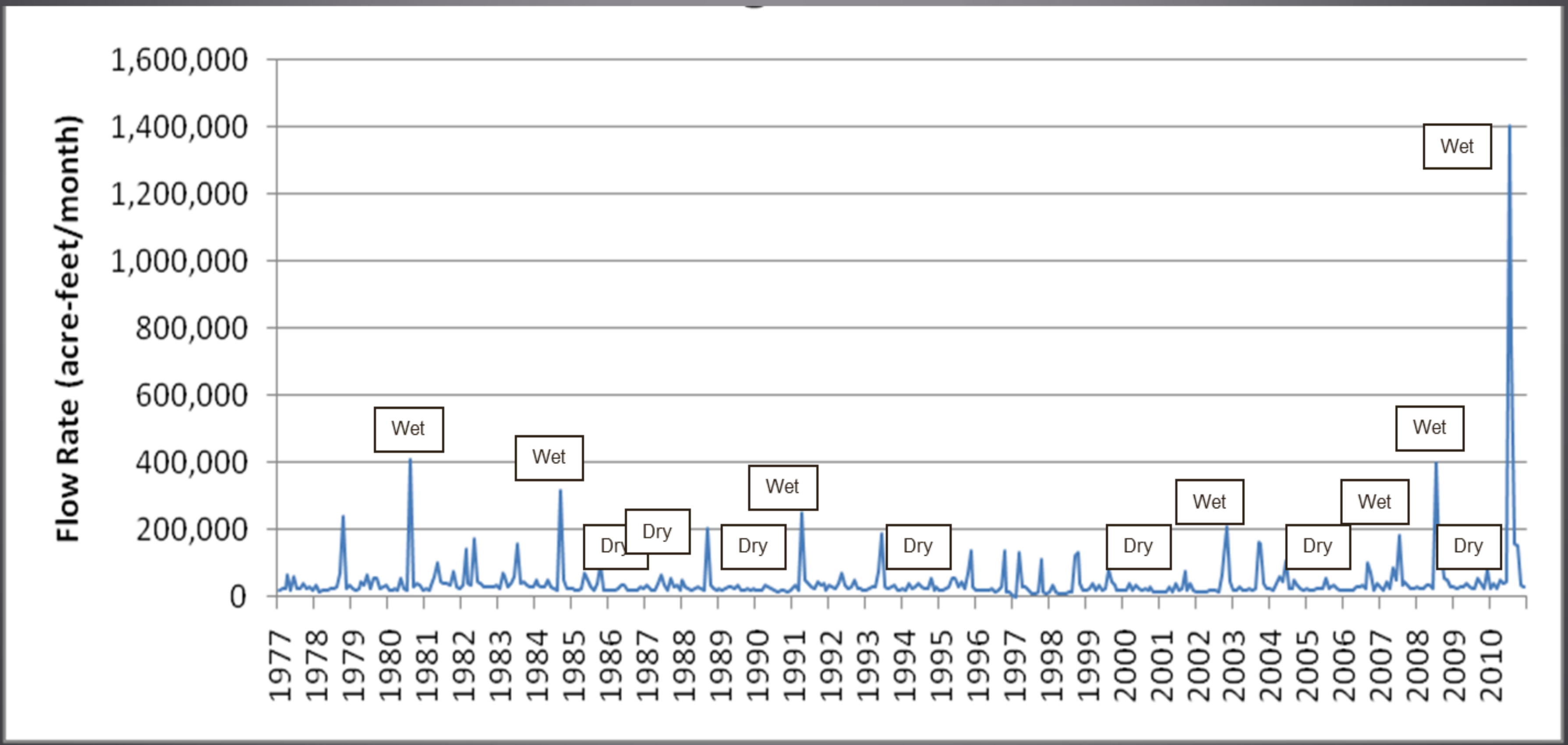
- Diversions

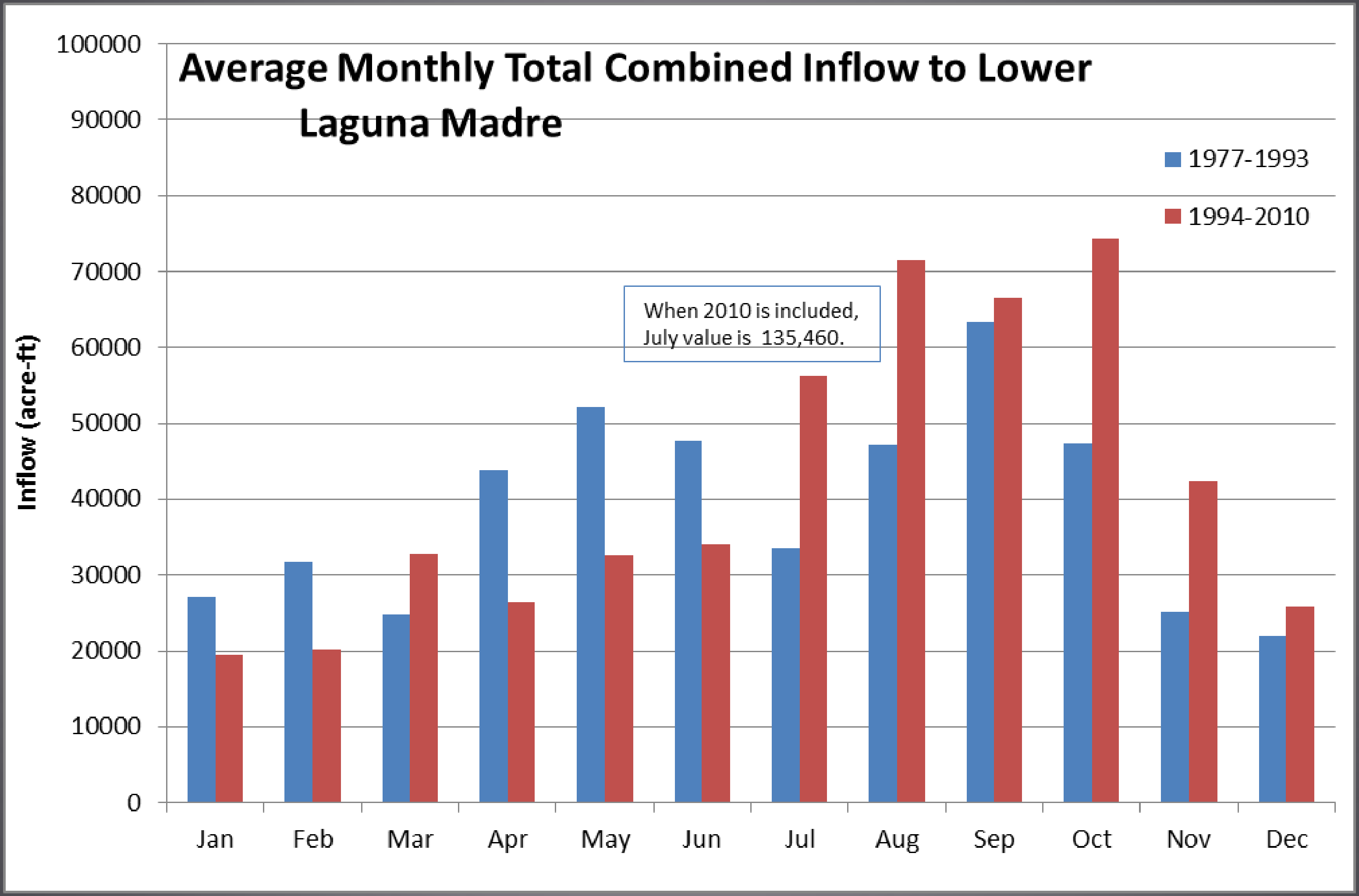
+ Returns

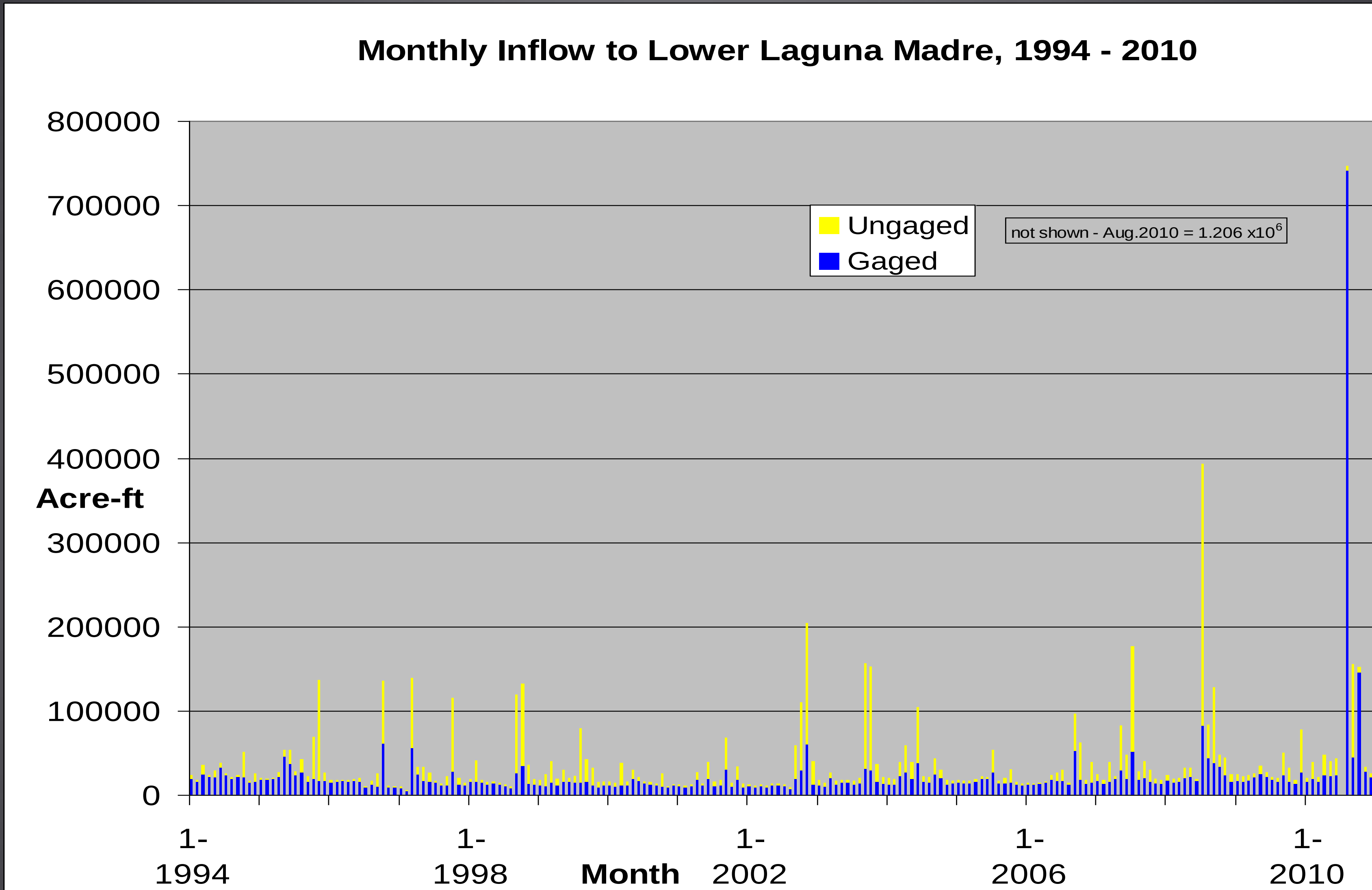
= Total Surface Inflow

Gaged watersheds shown in cross-hatching; ungaged, all others

Monthly Combined Freshwater Inflow to the Lower Laguna Madre




Average Monthly Total Combined Inflow to Lower Laguna Madre
Inflow (acre-ft)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1977-1993
1994-2010
When 2010 is included, July value is 135,460.
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Monthly Inflow to Lower Laguna Madre, 1994 - 2010
800000
700000
600000
500000
400000
300000
200000
100000
0
Acre-ft
Ungaged
Gaged
not shown - Aug.2010 = 1.206 x10^6
1-1994
1-1998
1-2002
1-2006
1-2010
Month

Ungaged discharge to Arroyo Colorado after local rainfall event

Nutrient Loading and Inflow Plume Effects on LLM

1) Evaluate nutrient loading data for Arroyo Colorado
2) Apply TxBLEND Model using Total Combined Inflow to Lower Laguna Madre
3) Calculate monthly average salinity output
4) Develop salinity contour maps in 2 psu increments
5) Perform sensitivity analyses for 3 wet year pulses
6) Identify inflow thresholds producing 2 psu plumes
7) Perform overlays of salinity plumes and seagrass change maps

Plant Nutrients: From the Arroyo to the LLM

- Include mostly inorganic molecules needed by primary producers (algae and plants) to grow and reproduce
  - Micronutrients such as iron, potassium, manganese, zinc
  - Macronutrients such as carbon, nitrogen and phosphorus
  - If one nutrient is lacking, organism will be stunted

Arroyo Nutrients

Table 8.3.2. Water quality averages for select parameters for the Arroyo Colorado at the Port of Harlingen for the period March 1977 to August 2010.

	Sp Cond	**Total NH4**	**Total NO3**	**Total Kjeldahl**	**Total PO4**	**Ortho PO4**	**Chl a**
	uS/cm	mg N/L	mg N/L	mg N/L	mg PO4/L	mg PO4/L	ug/L
Avg	4436	0.56	2.64	1.53	2.33	1.40	33.71
SD	1465	1.39	1.33	0.44	1.34	0.56	21.74
N	185	161	76	98	36	34	136

•Arroyo nutrient levels are high compared to other Texas waterways.

Nutrient loading rates are high but vary seasonally

Table 8.3.3. Seasonal nitrogen (DIN) and phosphate loading rates for the Arroyo Colorado. Loading rate estimates are based on TCEQ water quality data from the Port of Harlingen and flow values from the Harlingen IBWC gage for the period 1978-2009.

				Avg	**SD**	**Avg**	**SD**	**Avg**
	Avg 5-day flow	**DIN**	**TPO4**	**DIN Load**	**DIN Load**	**PO4 Load**	**PO4 Load**	**Load N/P ratio**
	acre-ft/day	n	n	kg/day	kg/day	kg/day	kg/day	molar
Winter	427.5	38	11	1379.8	1961.7	496.0	347.2	6.4
Spring	569.4	46	7	1319.0	1578.9	923.9	1093.9	3.3
Summer	446.8	46	10	990.0	1935.3	344.5	77.6	6.6
Fall	548.3	31	8	957.0	1045.0	715.5	736.5	3.1

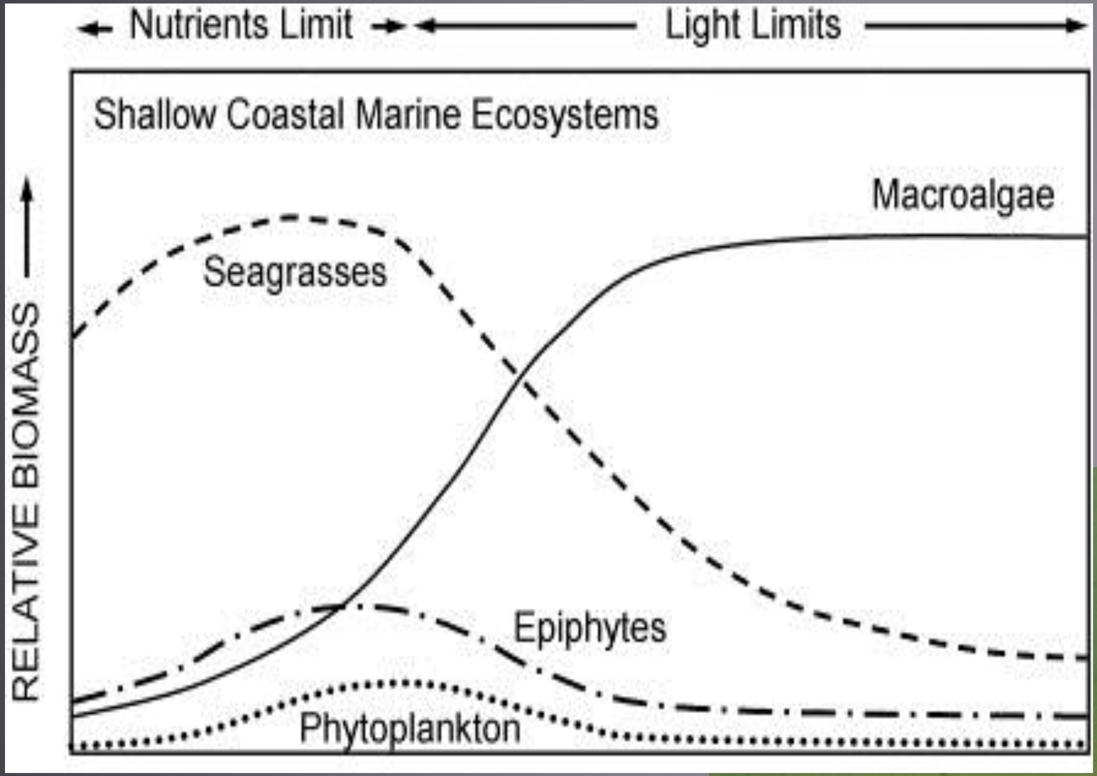
Nutrients encourage the growth of LLM primary producers

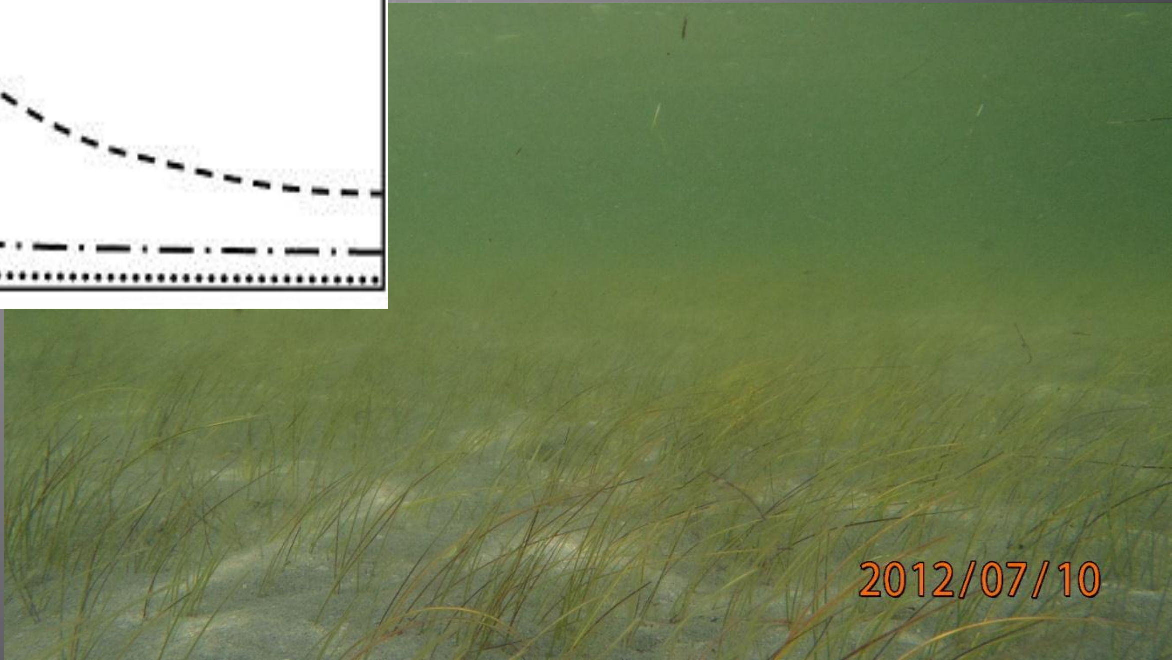
Seagrass epiphytes

Texas brown tide

Excessive seaweed growth

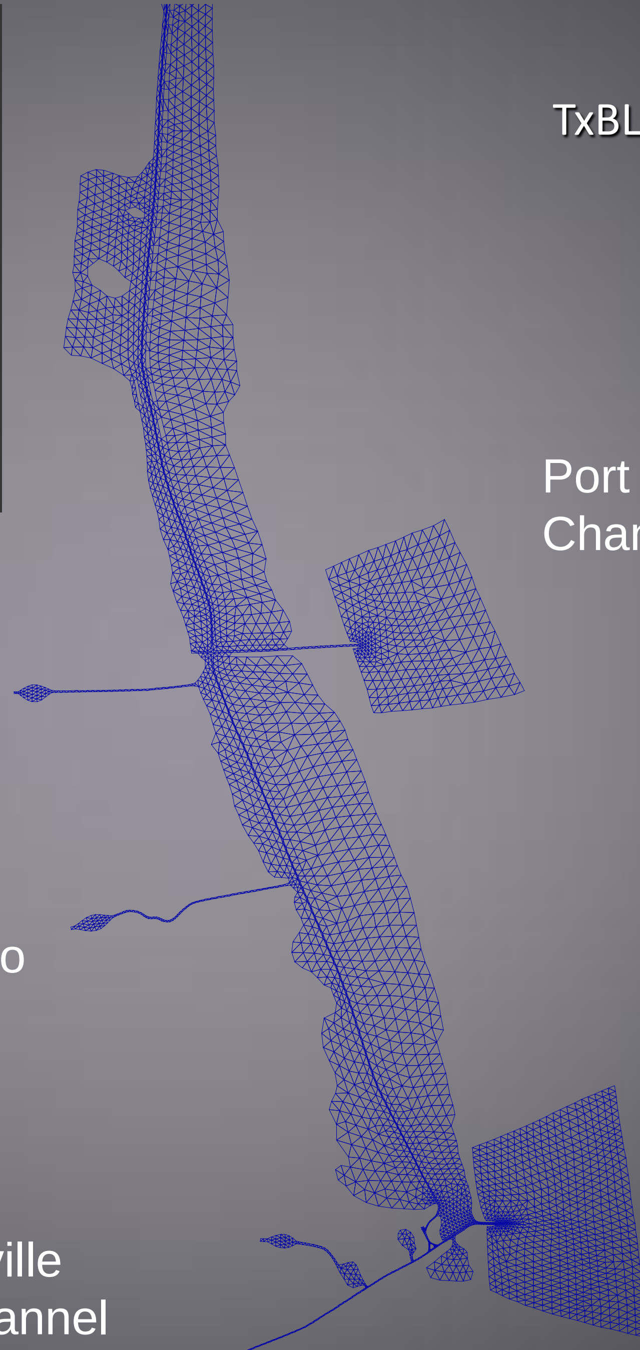
Seagrasses can be affected indirectly by high nutrient levels



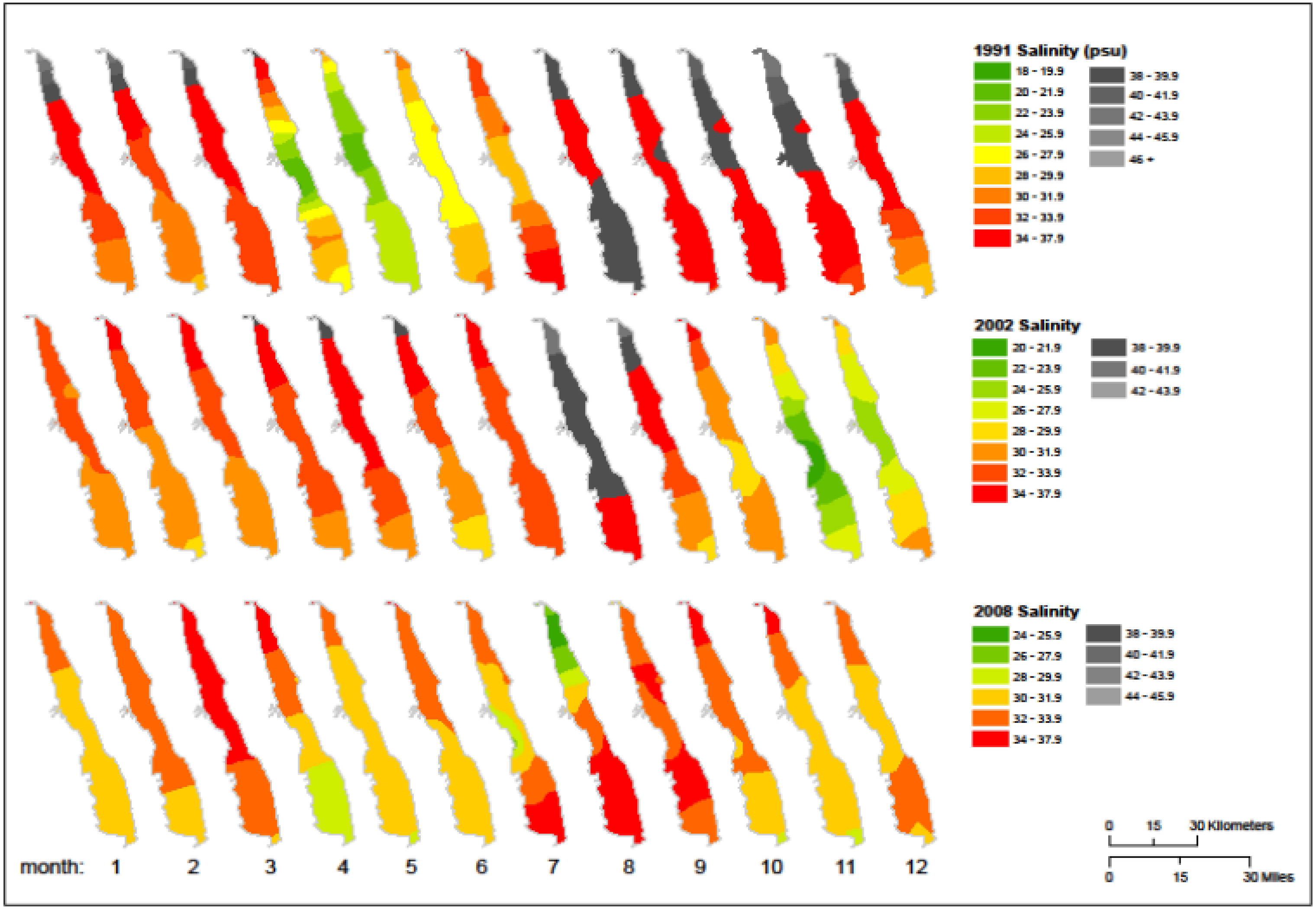


Laguna Madre TxBLEND Hydrodynamic & Salinity Transport Model

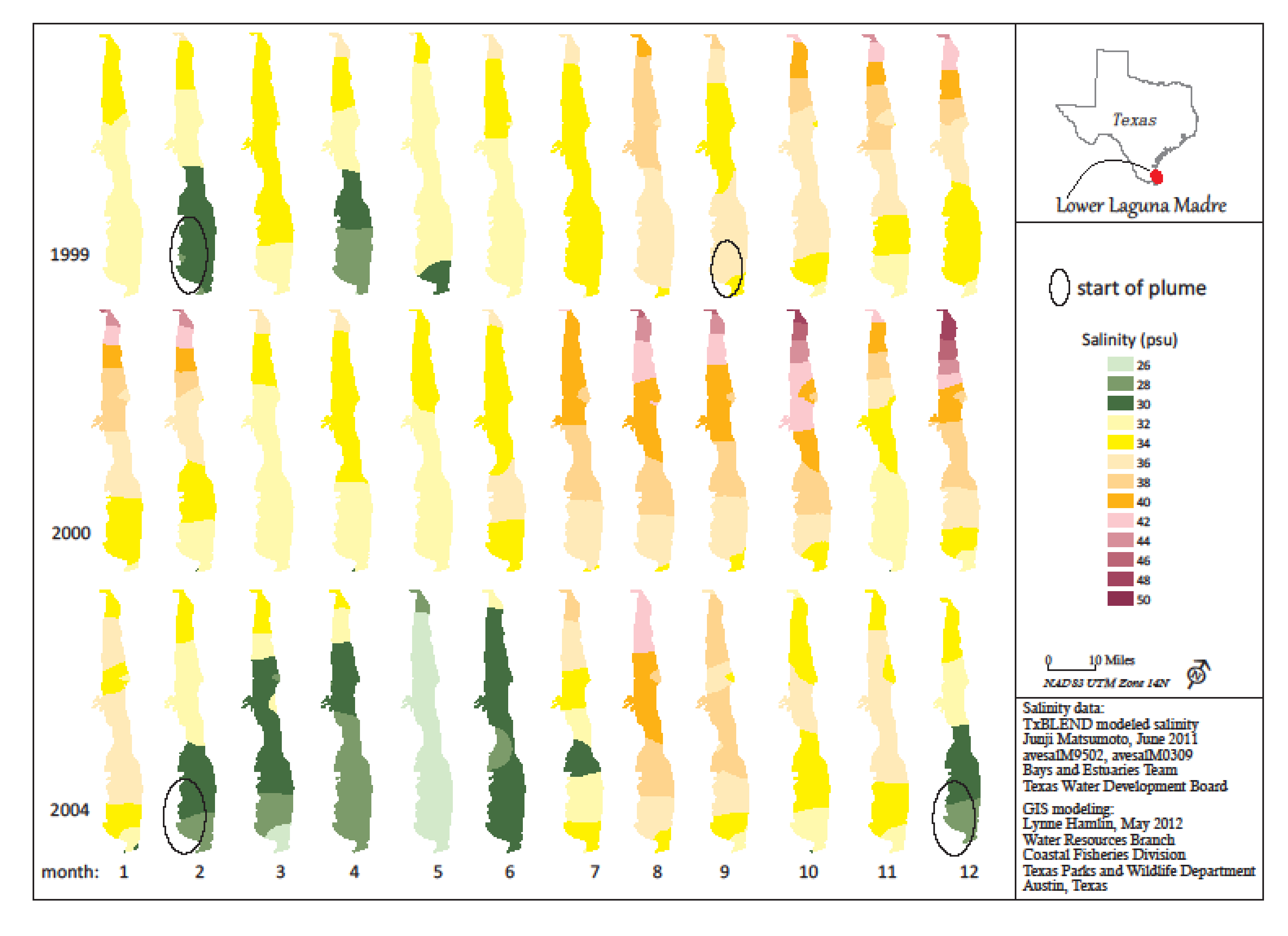
TxBLEND Model Grid

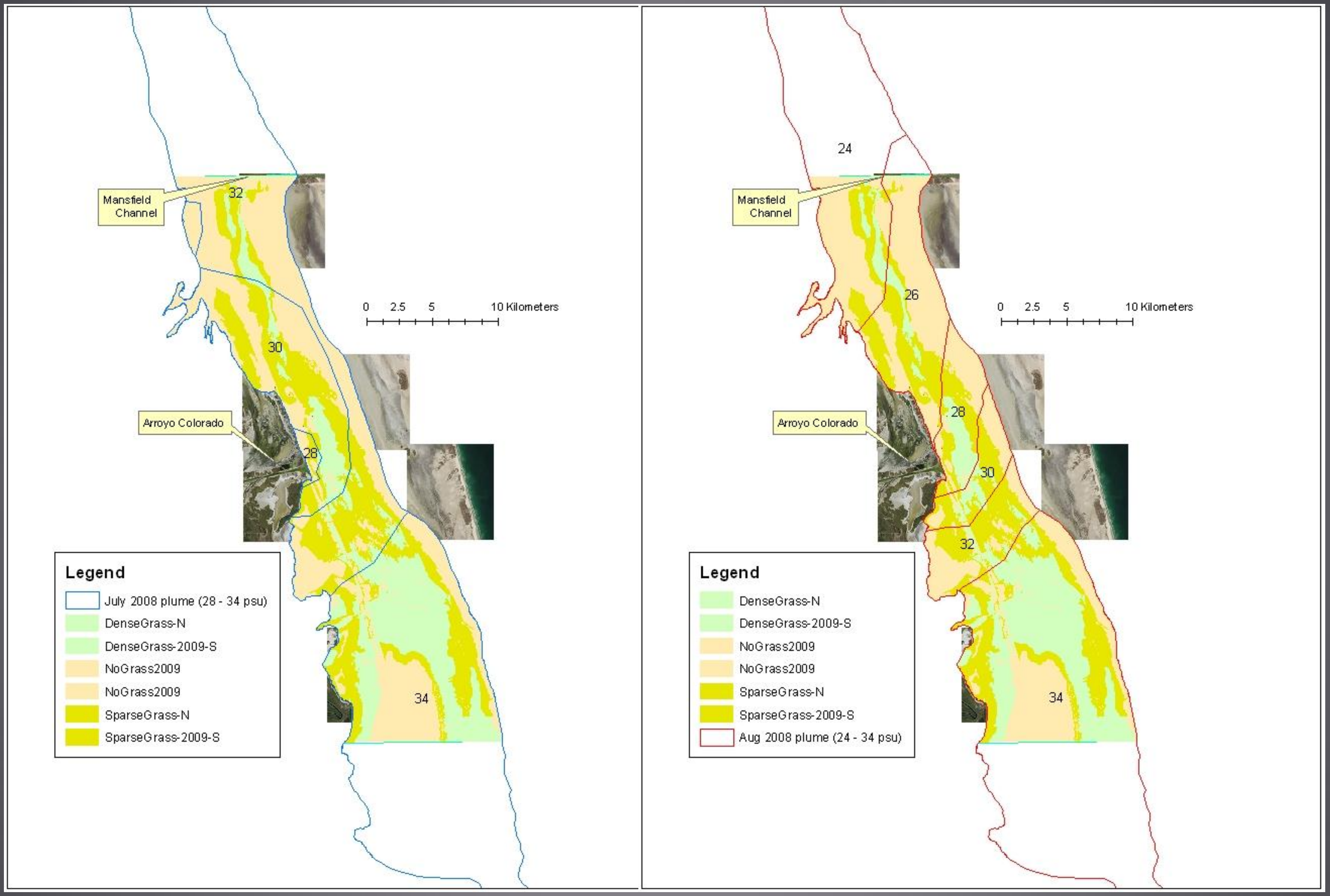


TxBLEND Model Monthly Salinity Contours of Lower Laguna Madre

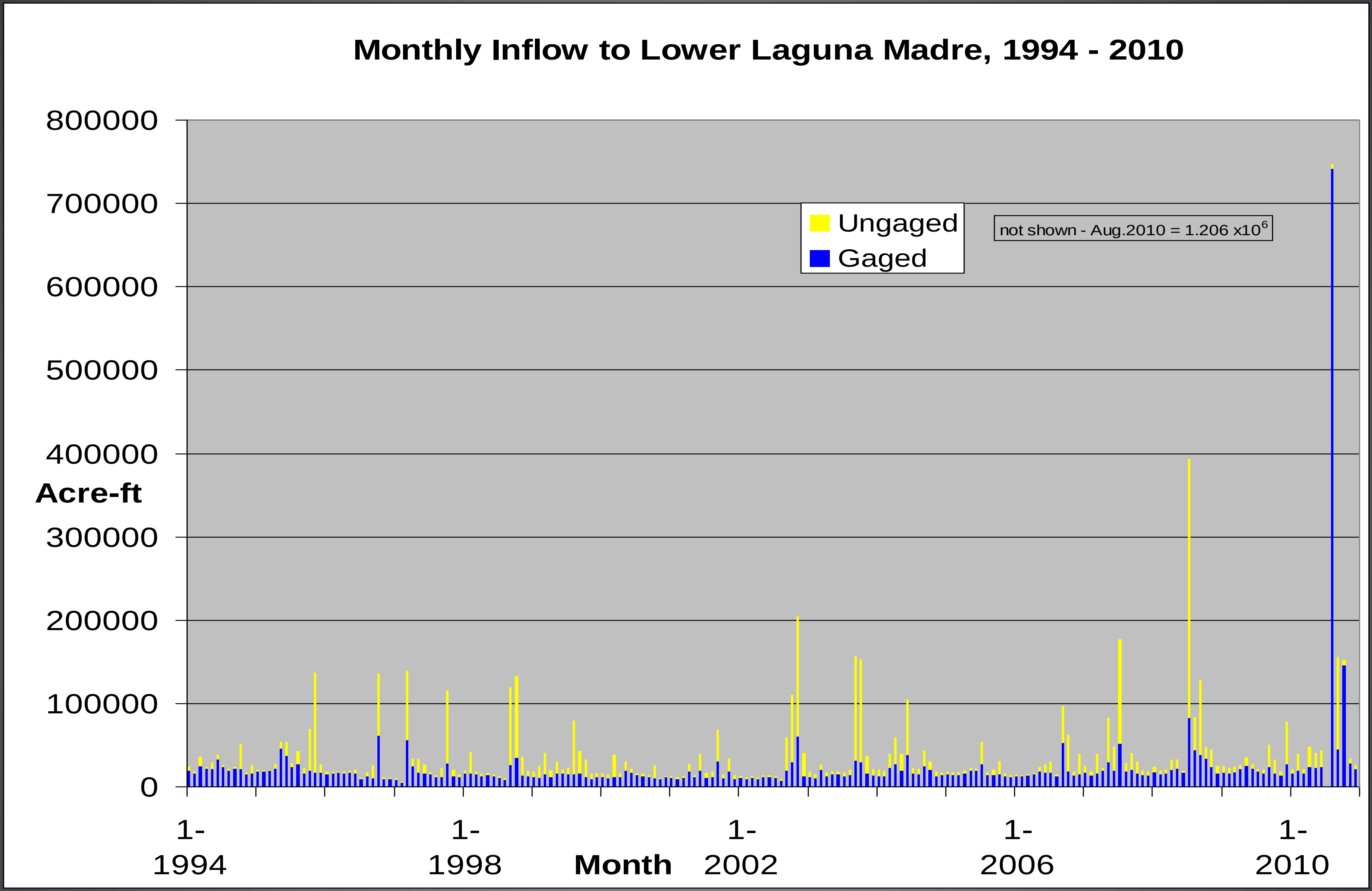


TxBLEND Model Monthly Salinity Contours of Lower Laguna Madre





Salinity plumes from July - Aug 2008 inflows overlaid onto 2009 seagrass



Monthly Inflow to Lower Laguna Madre, 1994 - 2010
800000
700000
600000
500000
400000
300000
200000
100000
0
Acre-ft
Ungaged
Gaged
not shown - Aug.2010 = 1.206 x10^6
1-1994
1-1998
1-2002
1-2006
1-2010
Month

Freshwater Inflow Effects on LLM Seagrass Ecosystem (modified)

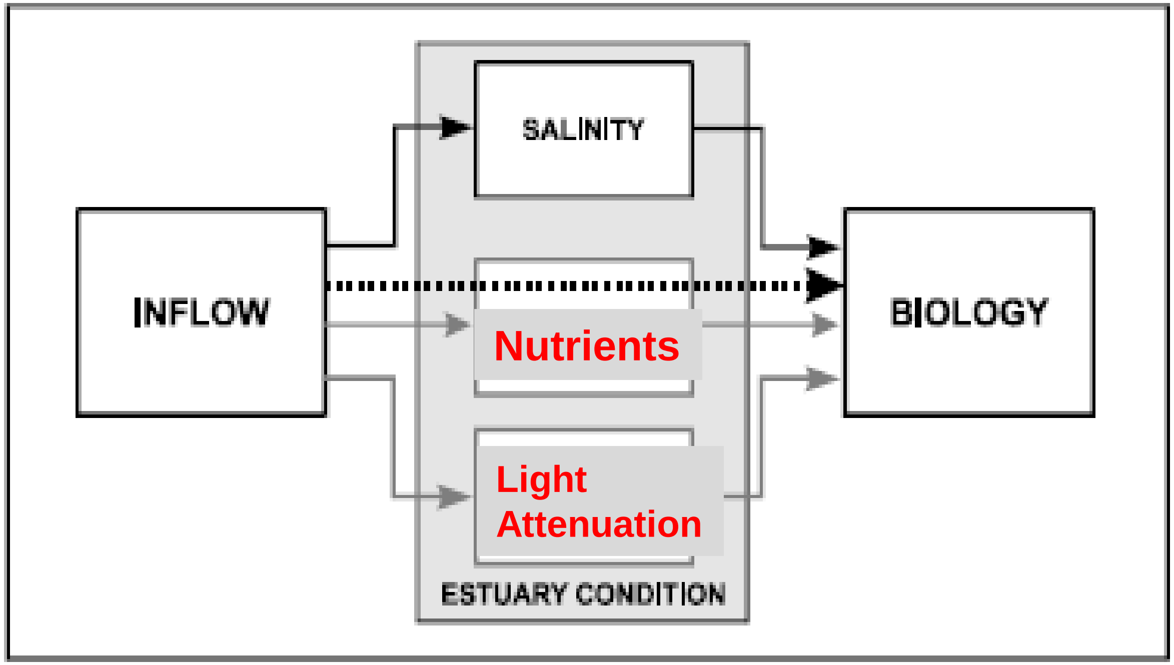


Figure 2.1-2 – Schematic of Relation of "Biology" to "Inflow"
(Compressed from Figure 2.2-1)

Three Categories of Inflow Regimes affecting Seagrasses

Flow Regimes	Years of Occurrence	Monthly Pulses (acre-ft)	Ga/Ung Ratio
LOW	(8) 1986 – 87, 1989 – 90, 1994, 2000, 2005, 2009	< 40,000	3 or more to 1
HIGH	(12) 1984, 1988, 1991, 1993, 1997-98, 2002 – 2004, 2007 – 08, 2010	>100,000 (generally 2 months consecutively)	mostly 0.4 to 1
INTERMEDIATE	(9) 1982-83, 1985, 1992, 1995 – 96, 1999, 2001, 2006	50,000 – 85,000 (often 2 + months consecutively)	1.2 – 2 to 1

Combined Inflow Percentiles to Lower Laguna Madre Dry Season Months (November – April) for years 1999-2008

		Existing Dry Season Inflows to Lower Laguna Madre	Natural Dry Season Inflows to Lower Laguna Madre	% of Nat Flows / Existing flows
	Units	**(ac-ft/month)**	**(ac-ft/month)**	**%**
Percentile	**Min**	12,446	1,426	11.5%
	0.05	13,537	1,895	14.0%
	0.1	14,109	2,381	16.9%
	0.2	16,270	3,428	21.1%
	0.25	16,872	3,613	21.4%
	0.5	19,610	5,695	29.0%
	0.75	25,504	12,901	50.6%
	0.8	29,900	15,215	50.9%
	0.9	40,833	28,023	68.6%
	0.95	42,559	30,077	70.7%
	Max	205,357	170,970	83.3%
	Average	26,342	12,669	N/A
	Median	19,610	5,695	N/A
	St. Dev.	25,596	23,087	N/A

Combined Inflow Percentiles to Lower Laguna Madre Wet Season Months (May – October) for years 1999-2008

		Existing Wet Season Inflows to Lower Laguna Madre	Natural Wet Season Inflows to Lower Laguna Madre	% of Nat Flows / Existing flows
	Units	**(ac-ft/month)**	**(ac-ft/month)**	**%**
Percentile	**Min**	12,313	3,613	29.3%
	0.05	16,386	5,007	30.6%
	0.1	17,743	5,531	31.2%
	0.2	20,909	6,908	33.0%
	0.25	21,214	7,888	37.2%
	0.5	31,213	14,445	46.3%
	0.75	51,620	38,152	73.9%
	0.8	66,072	52,894	80.1%
	0.9	107,042	92,771	86.7%
	0.95	156,861	151,407	96.5%
	Max	393,204	338,325	86.0%
	Average	50,988	36,715	N/A
	Median	31,213	14,445	N/A
	St. Dev.	59,004	55,327	N/A

LLMRecommendation

- Freshwater inflow during the dry season (Nov-Apr) is between 3,613 and 12,901 acre-feet per month (daily avg flows of 61 to 217 cfs)
  - During at least 3 months
  - Does not exceed 217 cfs for more than 45 days during the season
  - Is not less than 61 cfs for more then 45 days during the season

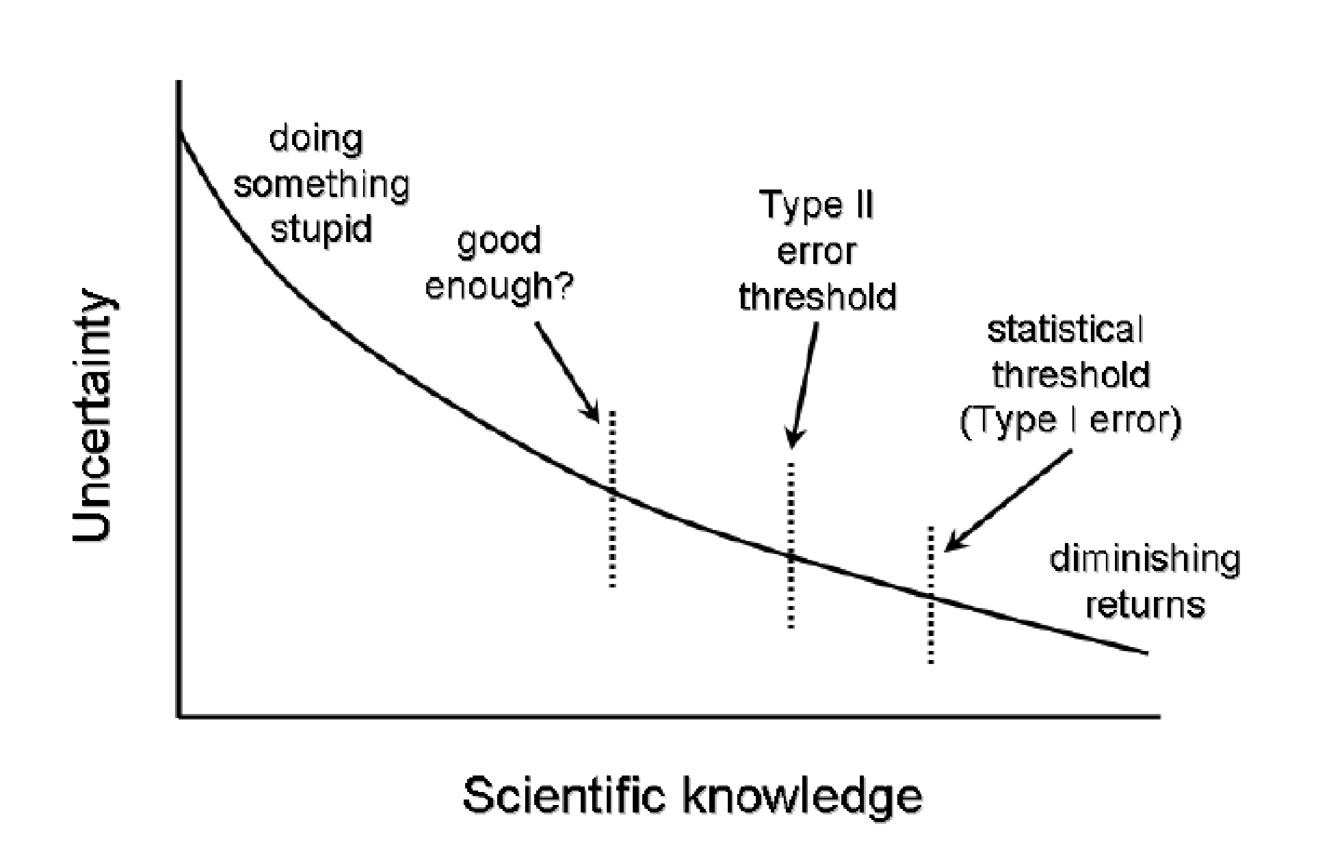
LLM Recommendation

- Freshwater inflow during the wet season (May-Oct) is between 7,888 and 38,152 acre-feet per month (daily avg flows of 133 to 641 cfs)
  - During at least 3 months
  - Does not exceed 641 cfs for more than 45 days during the season
  - Is not less than 133 cfs for more then 45 days during the season

Report Organization

- Section 1 Preamble
- Section 2 Hydrology
- Section 3 Lower Laguna Madre
- Section 4 Rio Grande Estuary
- Section 5 Ecological and hydrological characteristics above-tidal segment of the Rio Grande from above Anzalduas dam to El Jardin weir
- Section 6 Bahia Grande and San Martin Lake Complex
- Section 7 Resacas and Brownsville resaca watershed
- Section 8 Arroyo Colorado
- Section 9 Freshwater Inflow Analysis
- Section 10 Freshwater Inflow Recommendations
- Section 11 Adaptive Management
- Section 12 References
- Section 13 Appendices

Uncertainty



Uncertainty decreases as some function of increasing scientific knowledge. The statistical thresholds that define Type I errors (the likelihood of incorrectly inferring a relationship between variables when none exists) and Type II errors (the likelihood of incorrectly concluding no relationship when in fact one exists) are generally well established. The location of the "good enough" threshold is more nebulous, and shifts toward the right as the costs of making a mistake become greater.